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Matsushita et al.

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(54) **GLASS SHEET PROCESSING APPARATUS AND GLASS SHEET PRODUCING METHOD**

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CPC . ***B24B 9/10*** (2013.01); ***B24B 9/102*** (2013.01); ***B24B 9/105*** (2013.01)

(58) **Field of Classification Search**
CPC B24B 9/10; B24B 9/102; B24B 9/105
USPC 451/5, 44
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,813,823 A *	6/1974	Southland	B24B 3/06	451/217
4,575,970 A *	3/1986	Kozai	B24B 49/16	451/14
5,099,617 A *	3/1992	Bovone	B24B 9/10	451/231
5,713,784 A *	2/1998	Miller	B24B 9/107	451/14
6,344,259 B1 *	2/2002	Tanaka	B24B 9/10	428/192

(Continued)

FOREIGN PATENT DOCUMENTS

CN	2702813 Y	6/2005
JP	S46-16237 B	5/1971

(Continued)

OTHER PUBLICATIONS

International Search Report; PCT/JP2013/066060; Jul. 23, 2013.

(Continued)

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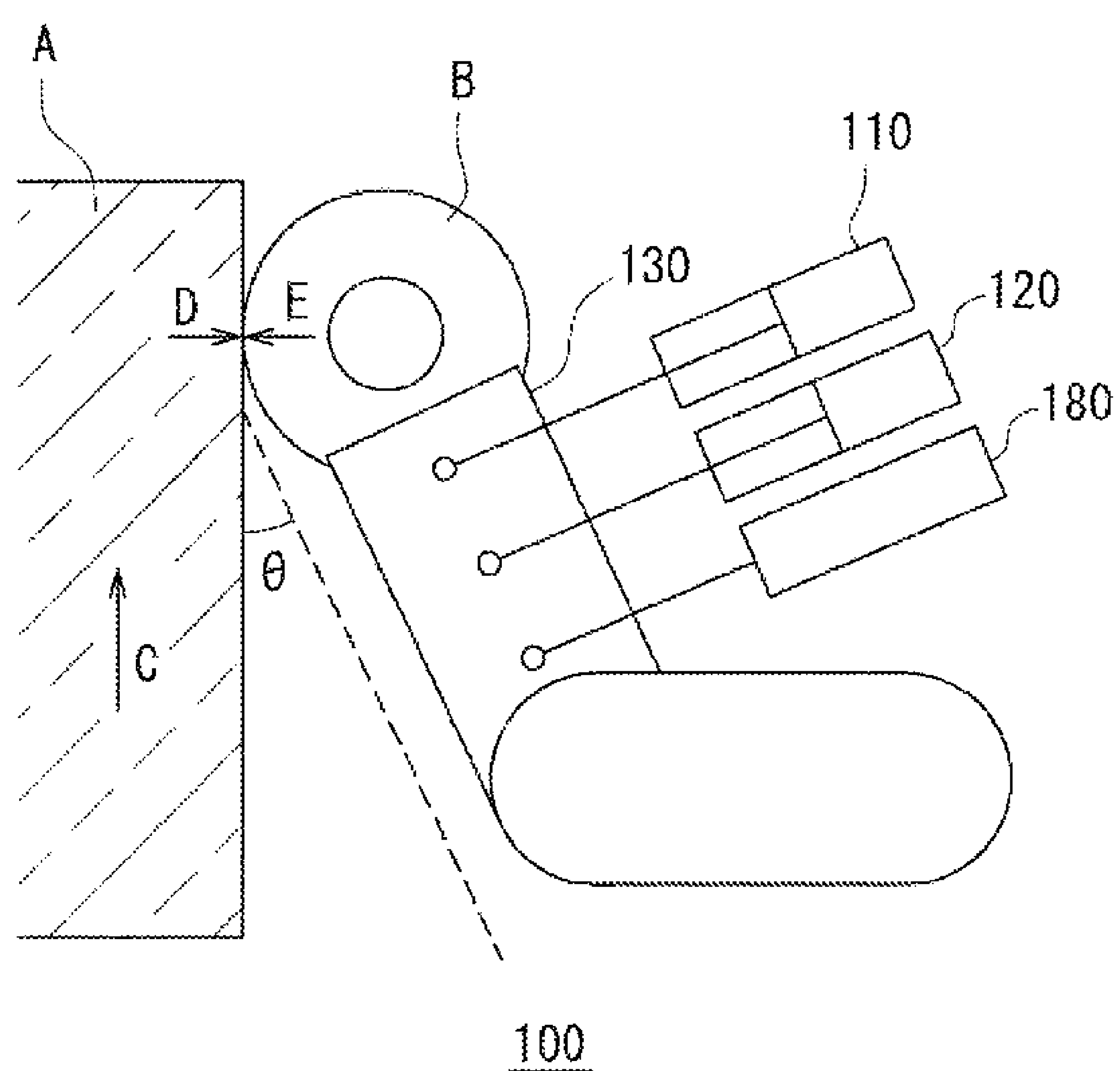
(74) *Attorney, Agent, or Firm* — Studebaker & Brackett PC

(57) **ABSTRACT**

A glass sheet processing apparatus processes an edge surface of a glass sheet using a processing tool. The glass sheet processing apparatus includes a pressing force generation element and a buffering element. The pressing force generation element generates a pressing force that the processing tool exerts on the edge surface of the glass sheet. The buffering element buffers an impact force that the edge surface of the glass sheet exerts on the processing tool.

14 Claims, 14 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

7,018,272	B2 *	3/2006	Allaire	B24B 9/102 451/11
7,207,866	B2	4/2007	Allaire et al.	
2005/0026541	A1	2/2005	Allaire et al.	
2006/0121832	A1	6/2006	Allaire et al.	
2015/0174724	A1 *	6/2015	Matsushita	B24B 9/102 451/44

FOREIGN PATENT DOCUMENTS

JP	S54-17595	A	2/1979
JP	S61-079559	A	4/1986
JP	H05-12072	U	2/1993
JP	H11-300612	A	11/1999
JP	2000-176804	A	6/2000
JP	2004-167633	A	6/2004
JP	2007-500605	A	1/2007
JP	2008-093744	A	4/2008

OTHER PUBLICATIONS

An Office Action issued by the Chinese Patent Office on Dec. 28, 2015, which corresponds to Chinese Patent Application No. 2013800303671 and is related to U.S. Appl. No. 14/407,039.

* cited by examiner

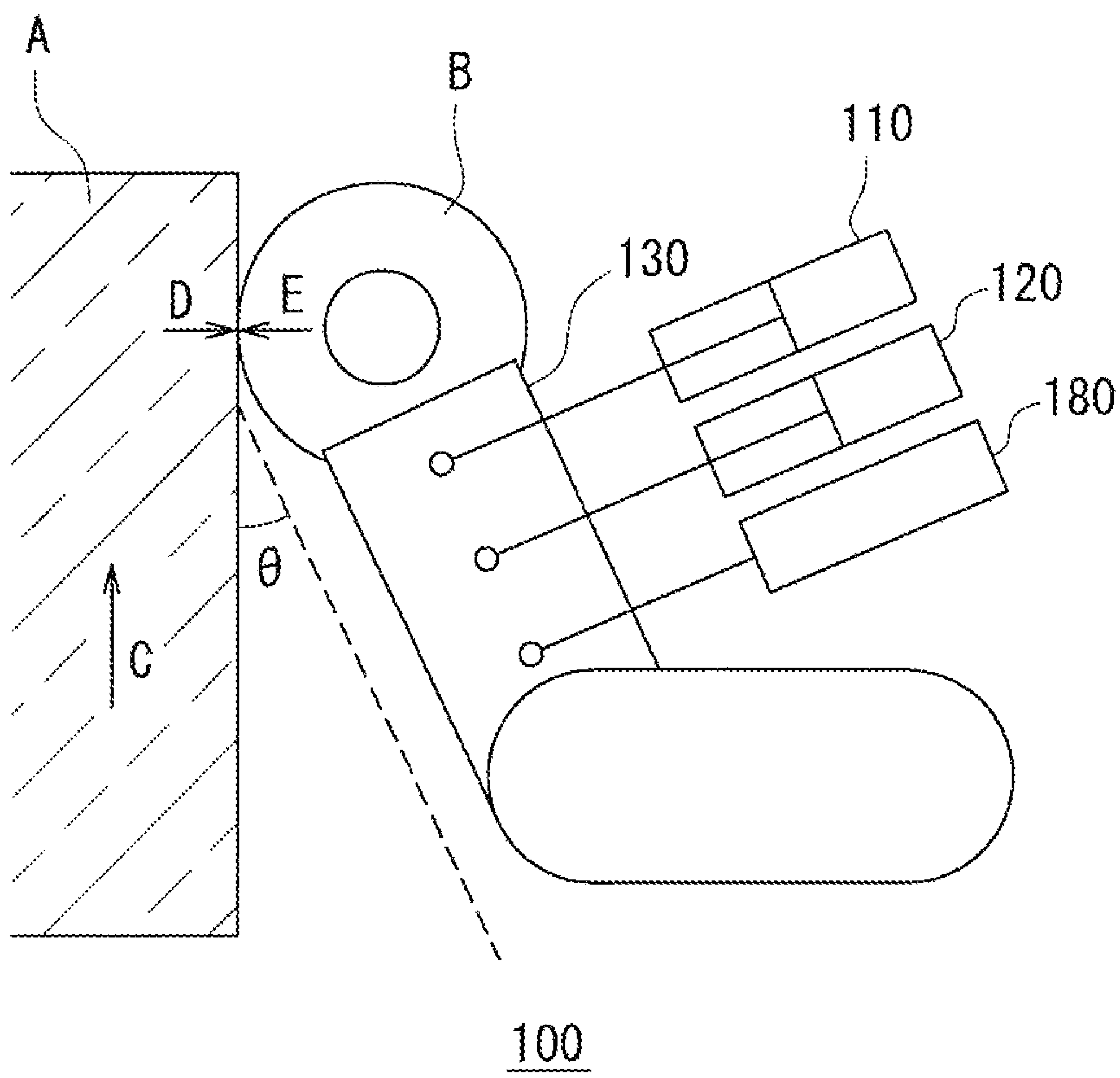


FIG. 1

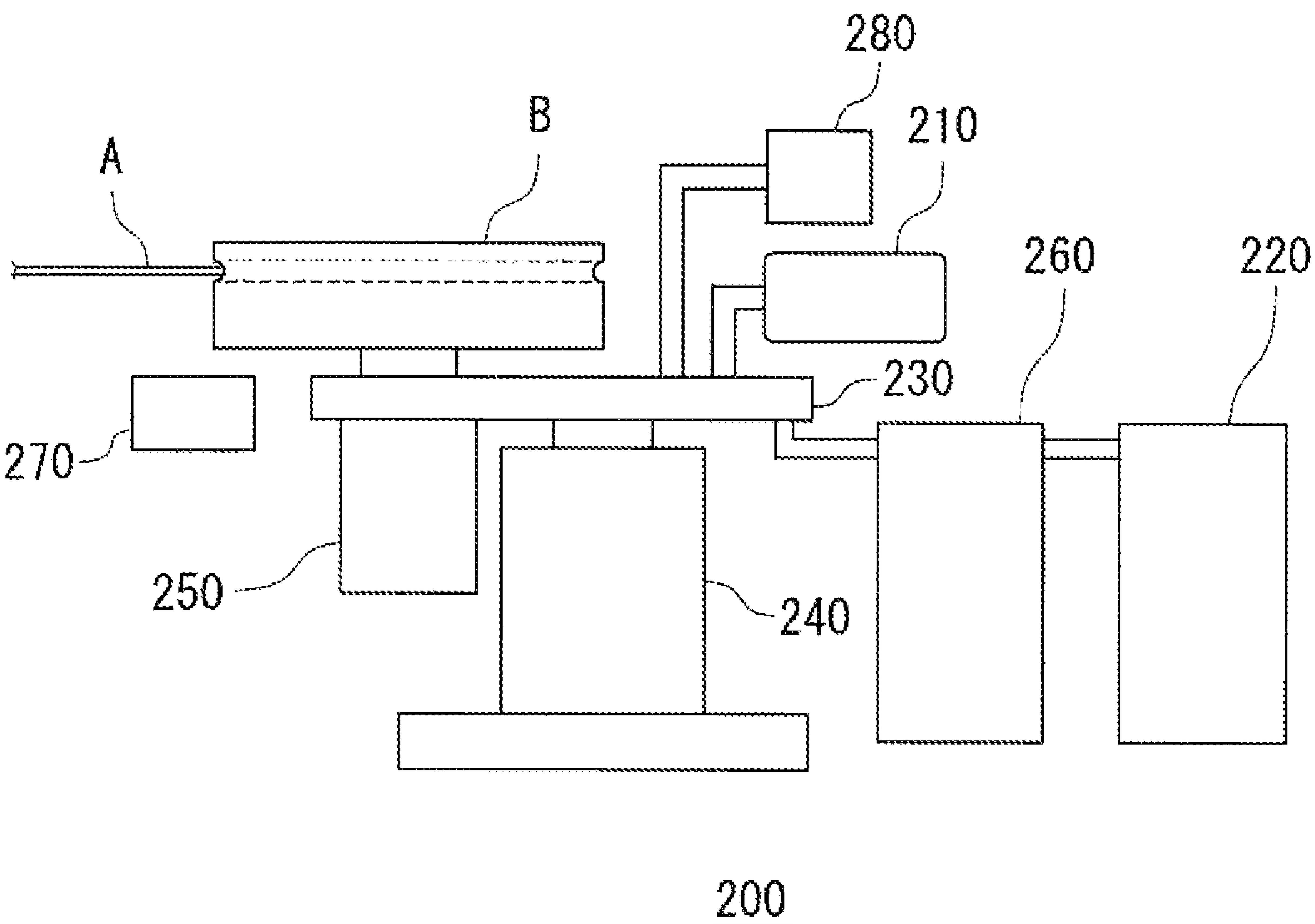


FIG. 2

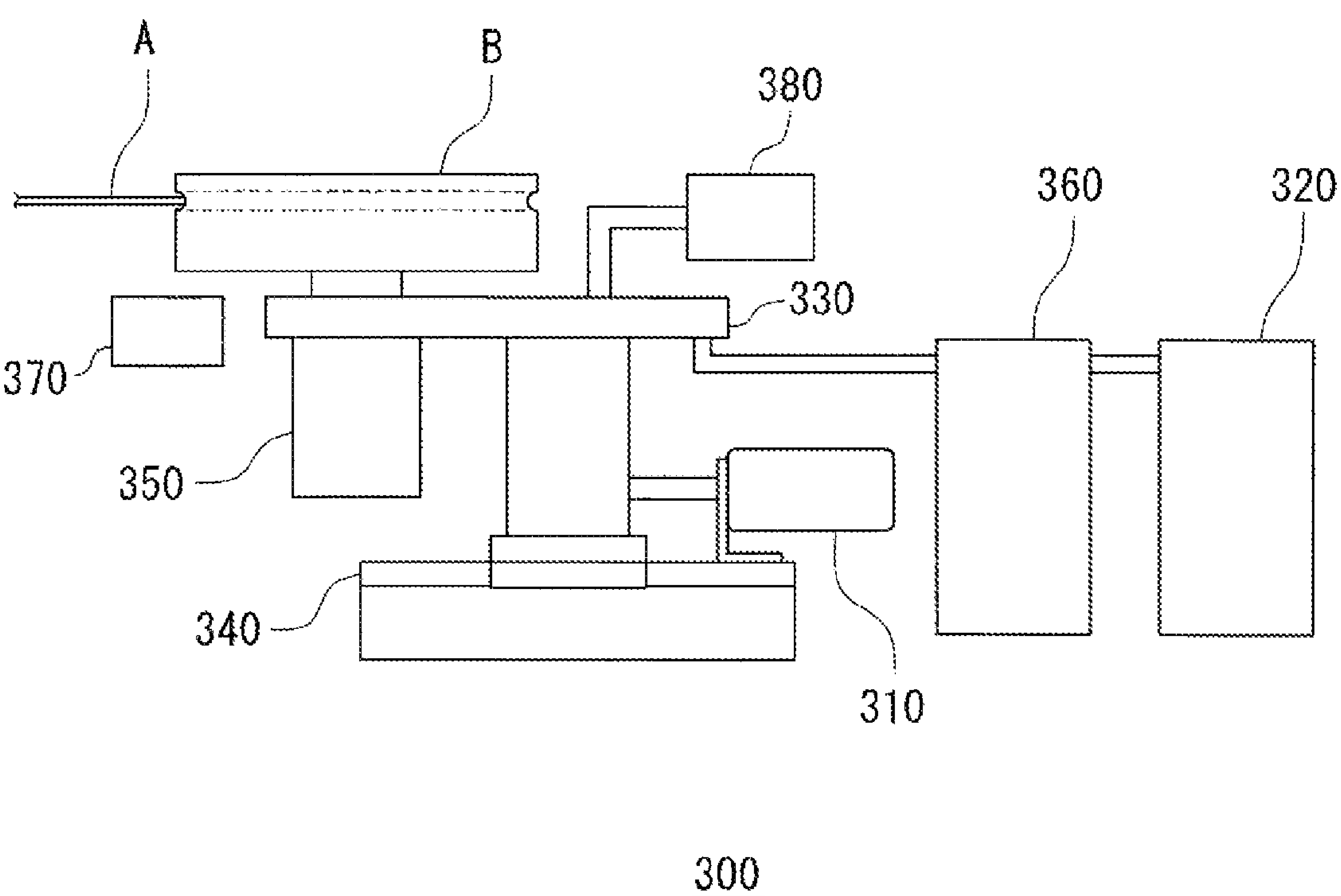


FIG. 3

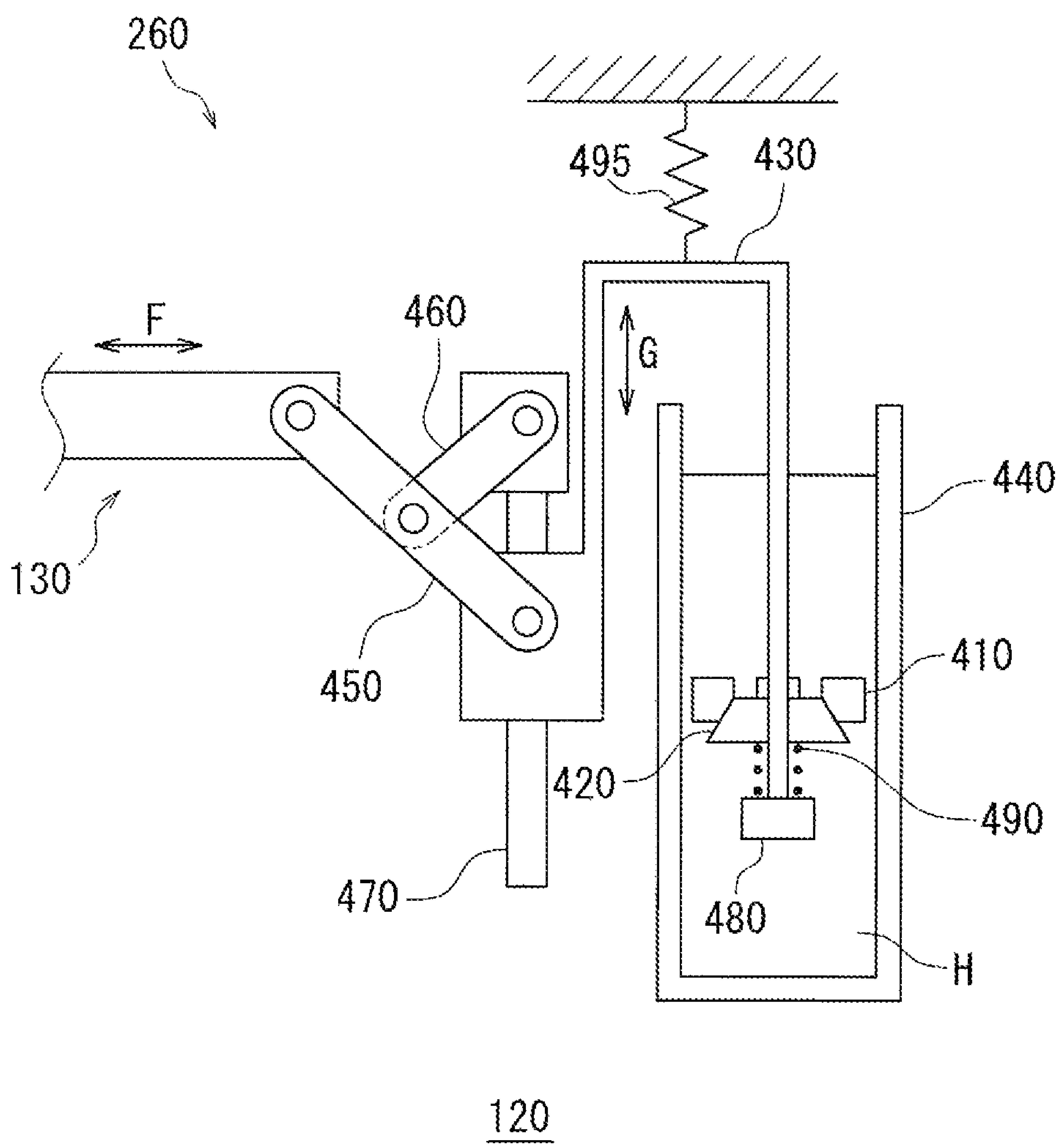


FIG. 4

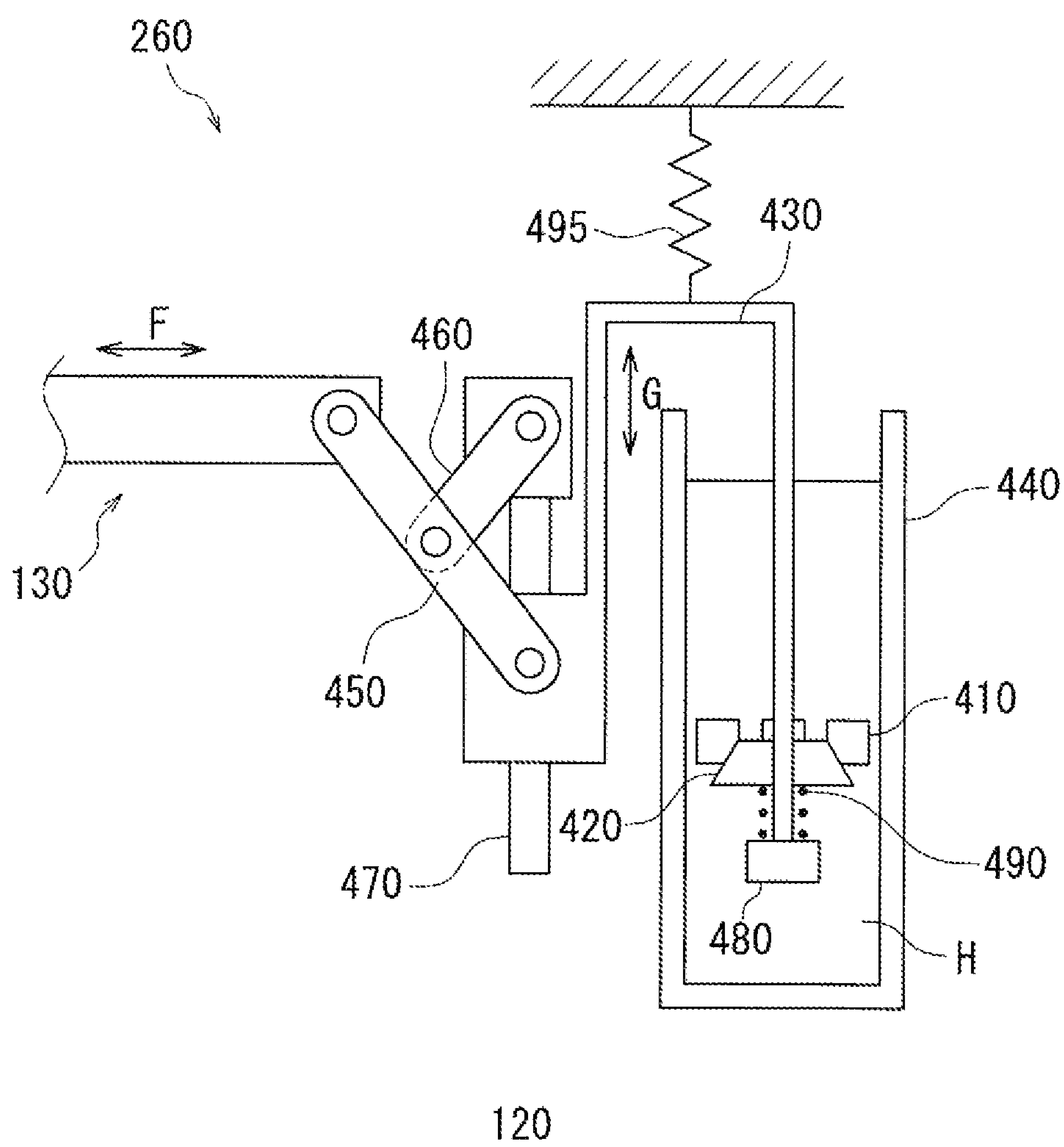


FIG. 5

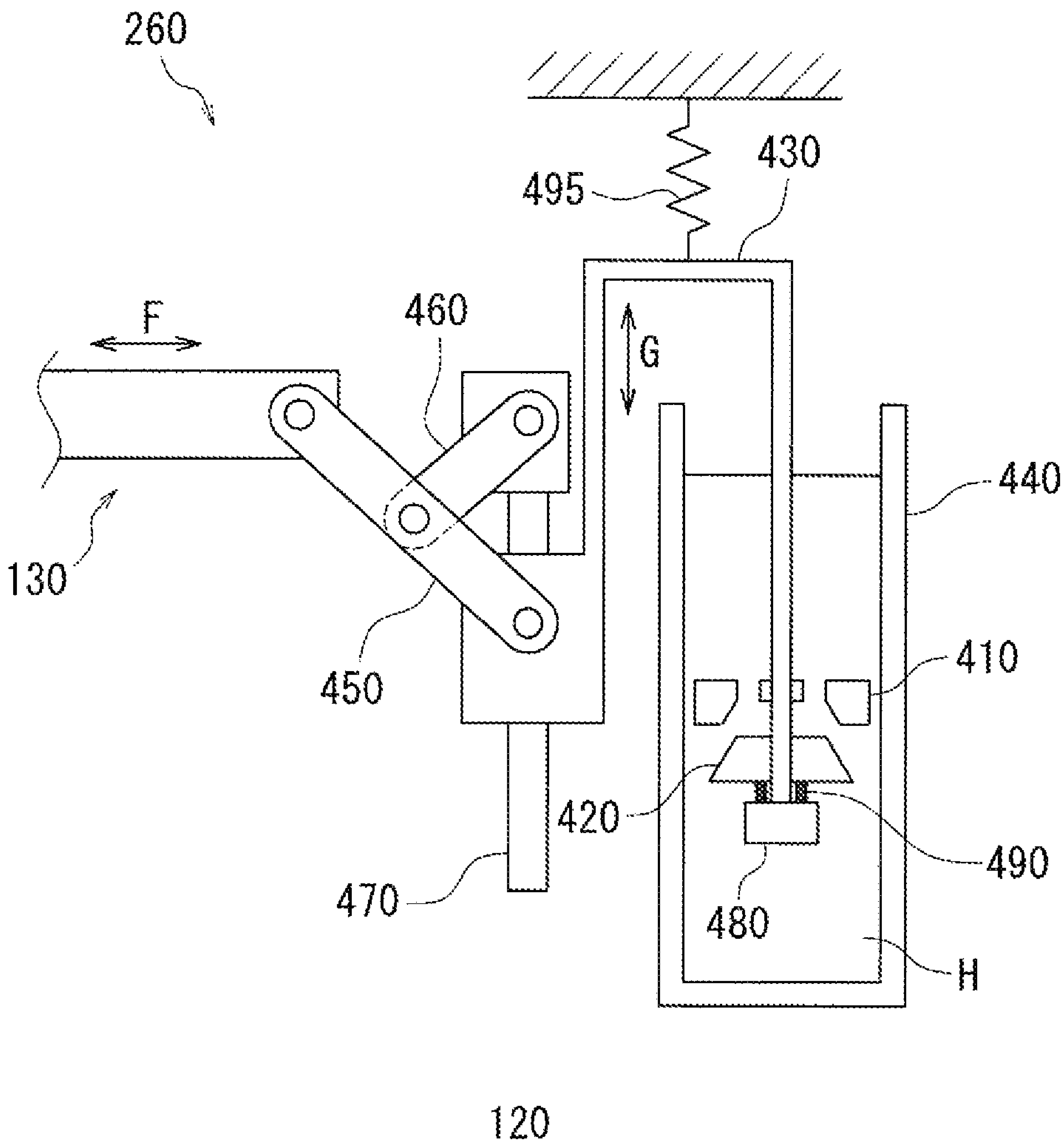


FIG. 6

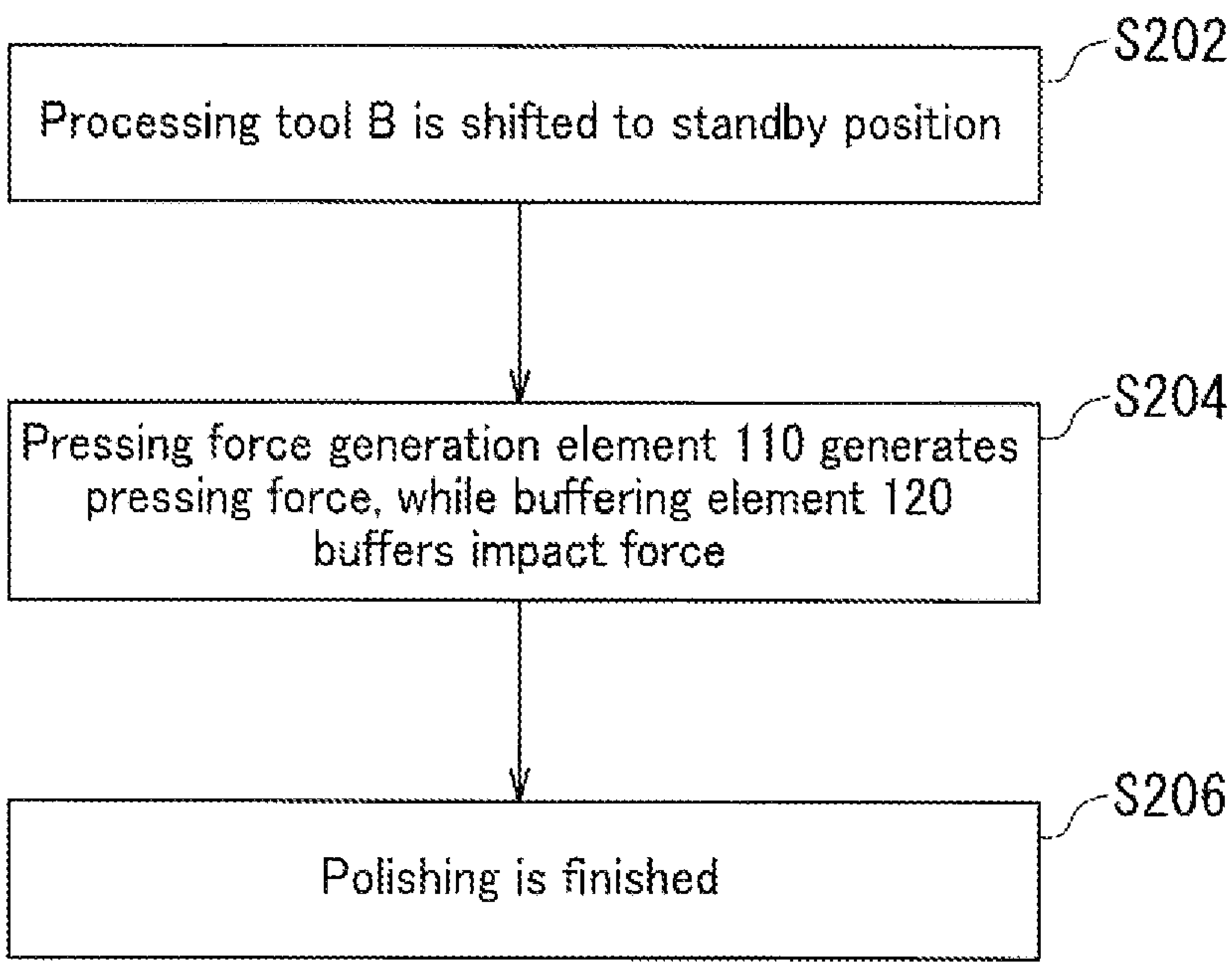

S202
Processing tool B is shifted to standby position
S204
Pressing force generation element 110 generates pressing force, while buffering element 120 buffers impact force
S206
Polishing is finished

FIG. 7

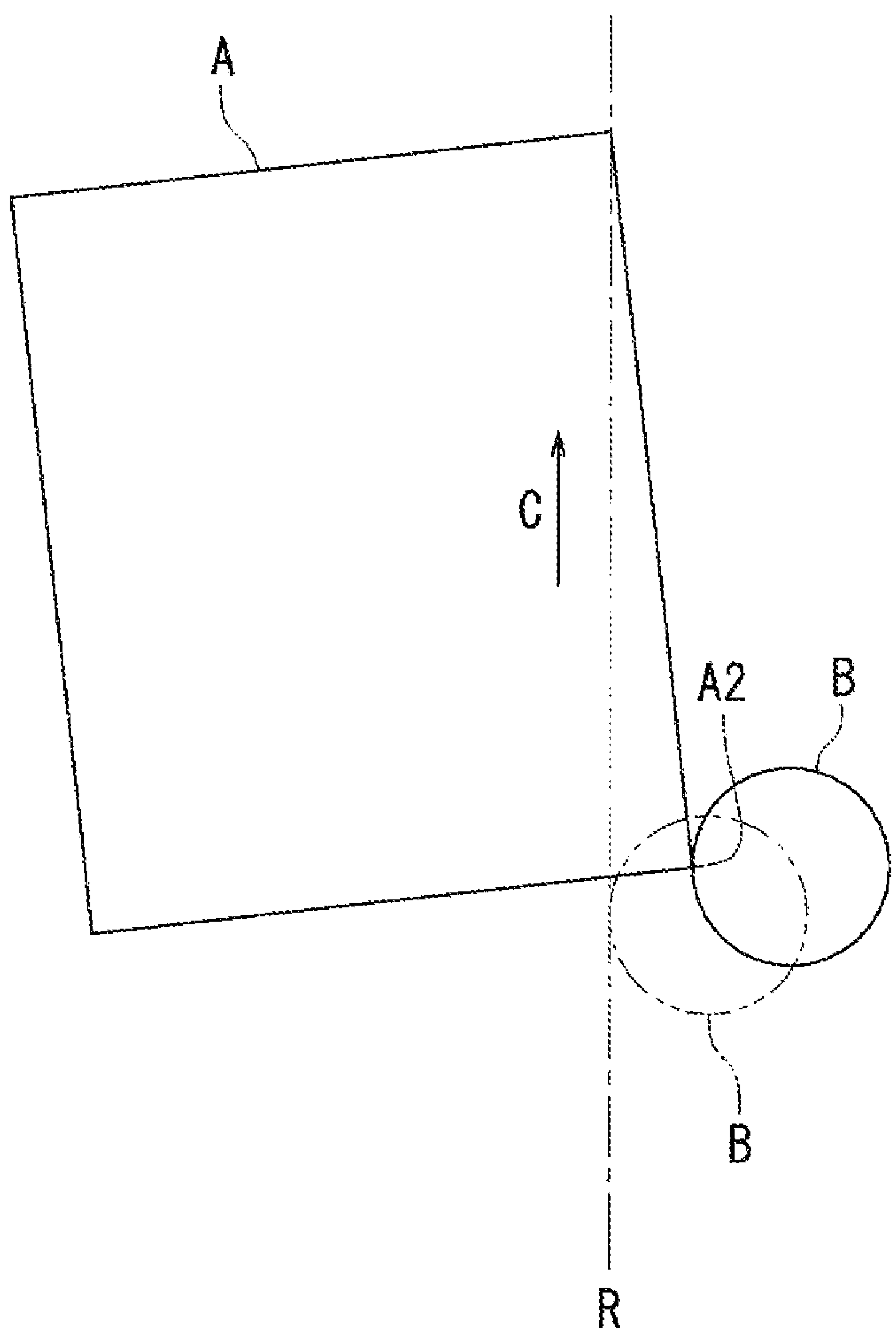


FIG. 8

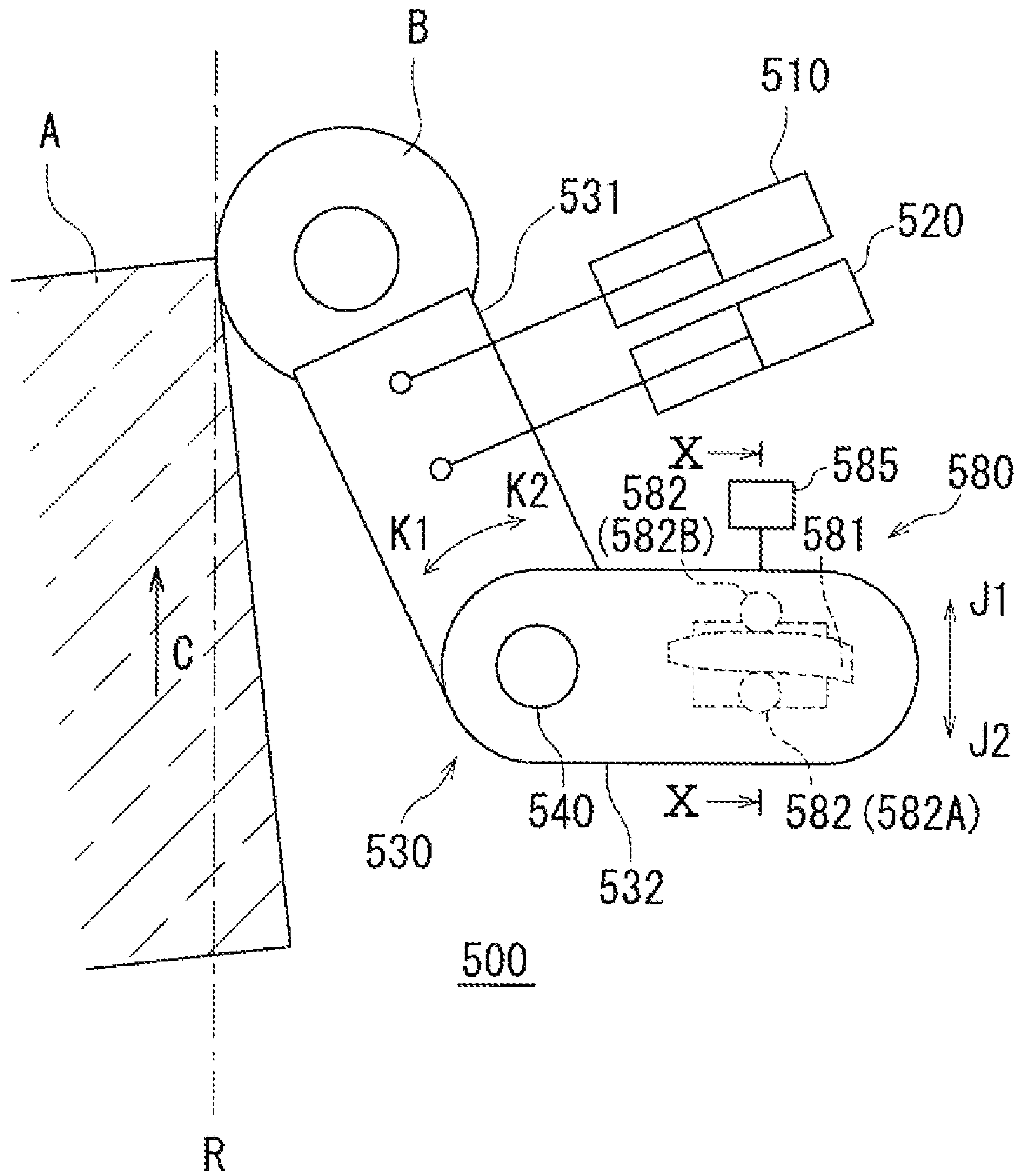

B
A
510
531
520
X
585
580
582
(582B)
581
K2
K1
J1
C
J2
540
X
582 (582A)
530
532
500
R

FIG. 9

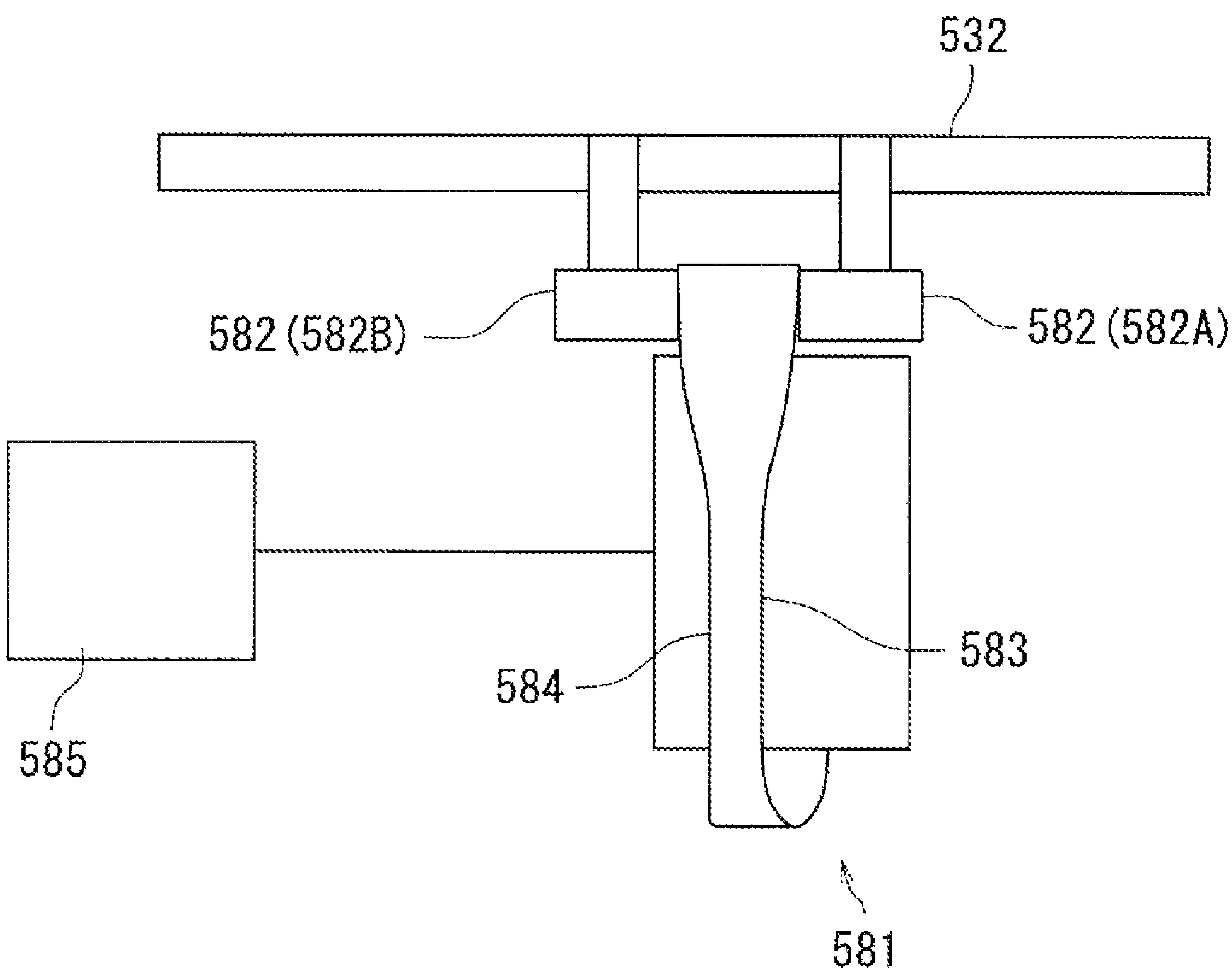


FIG. 10

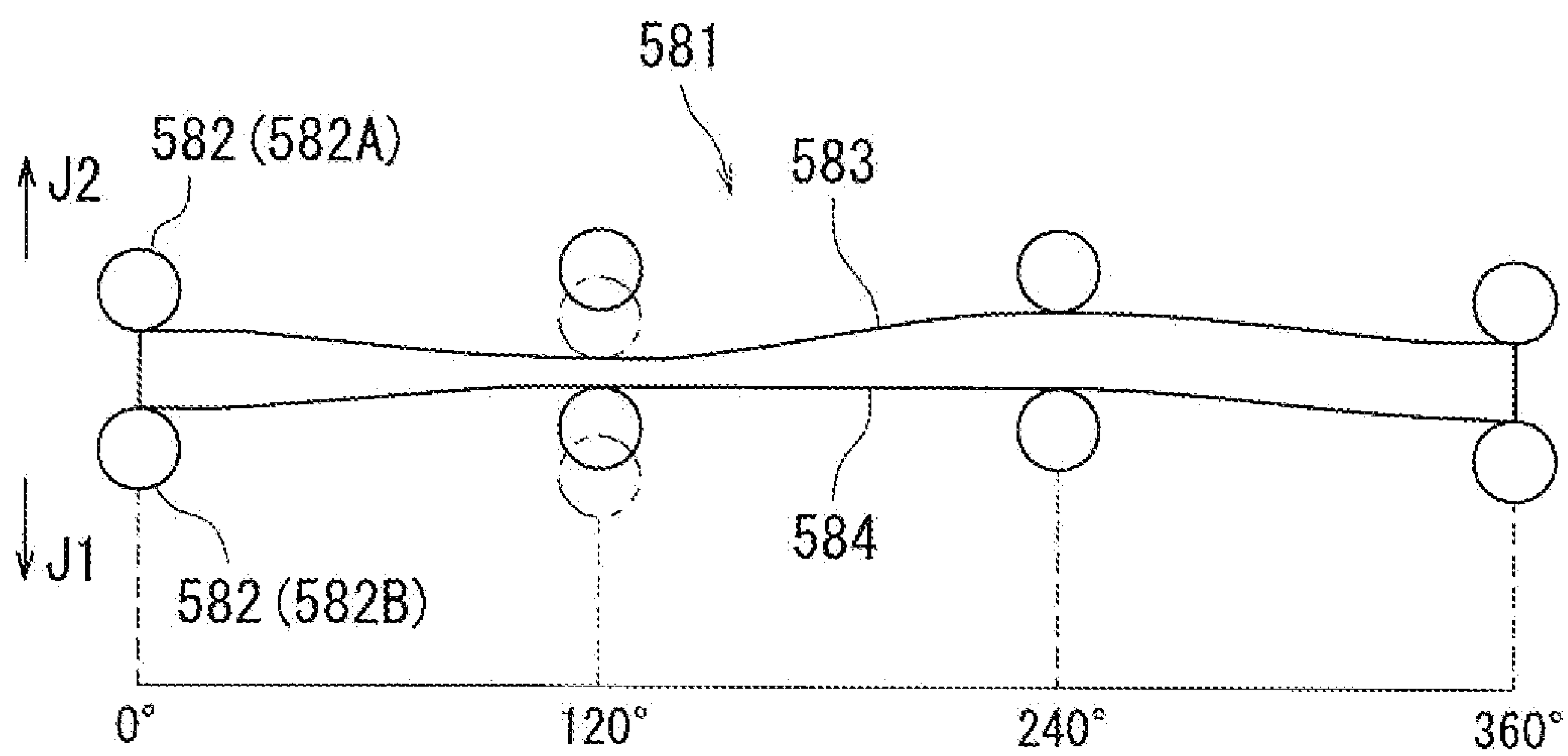


FIG. 11

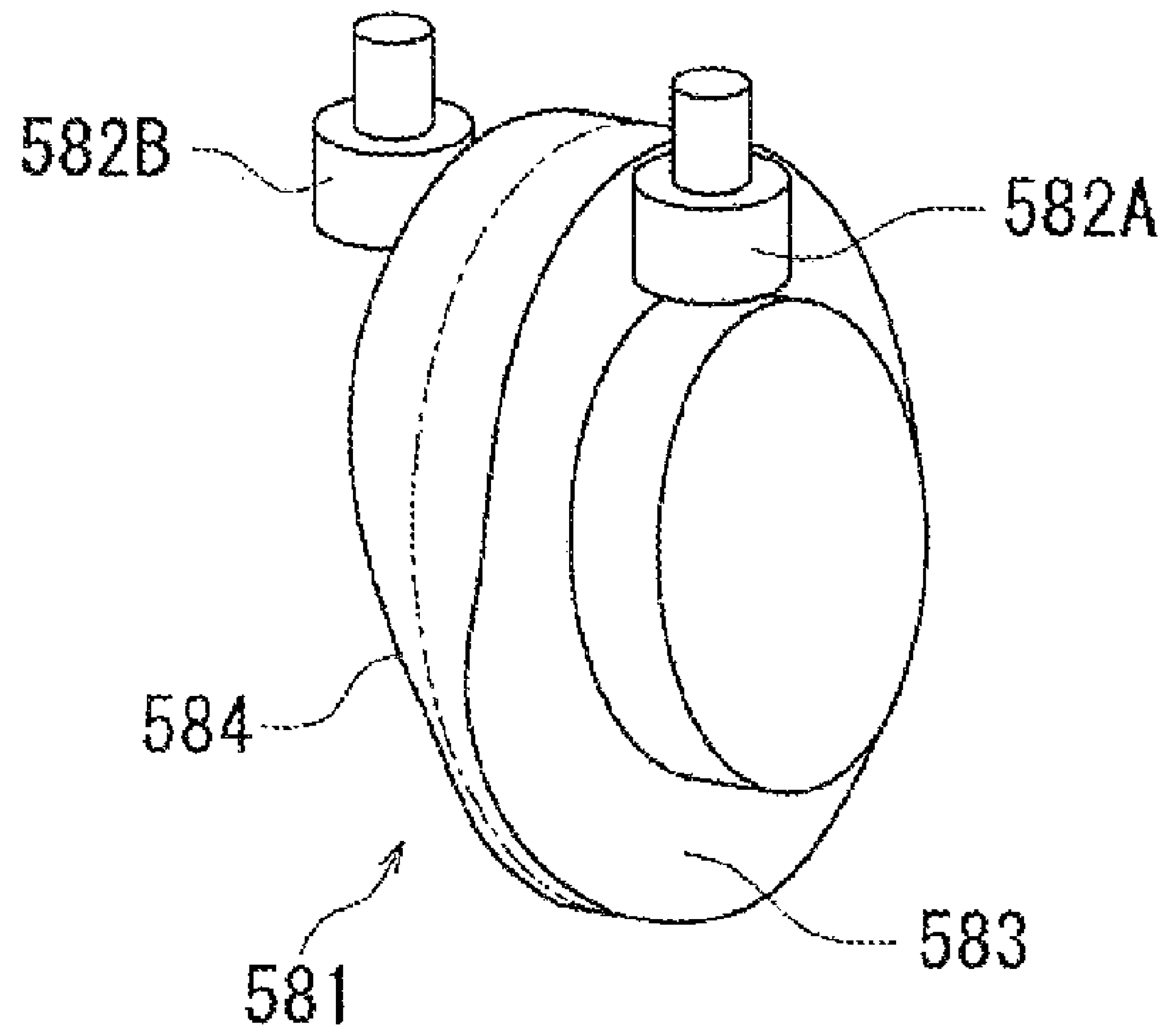


FIG. 12A

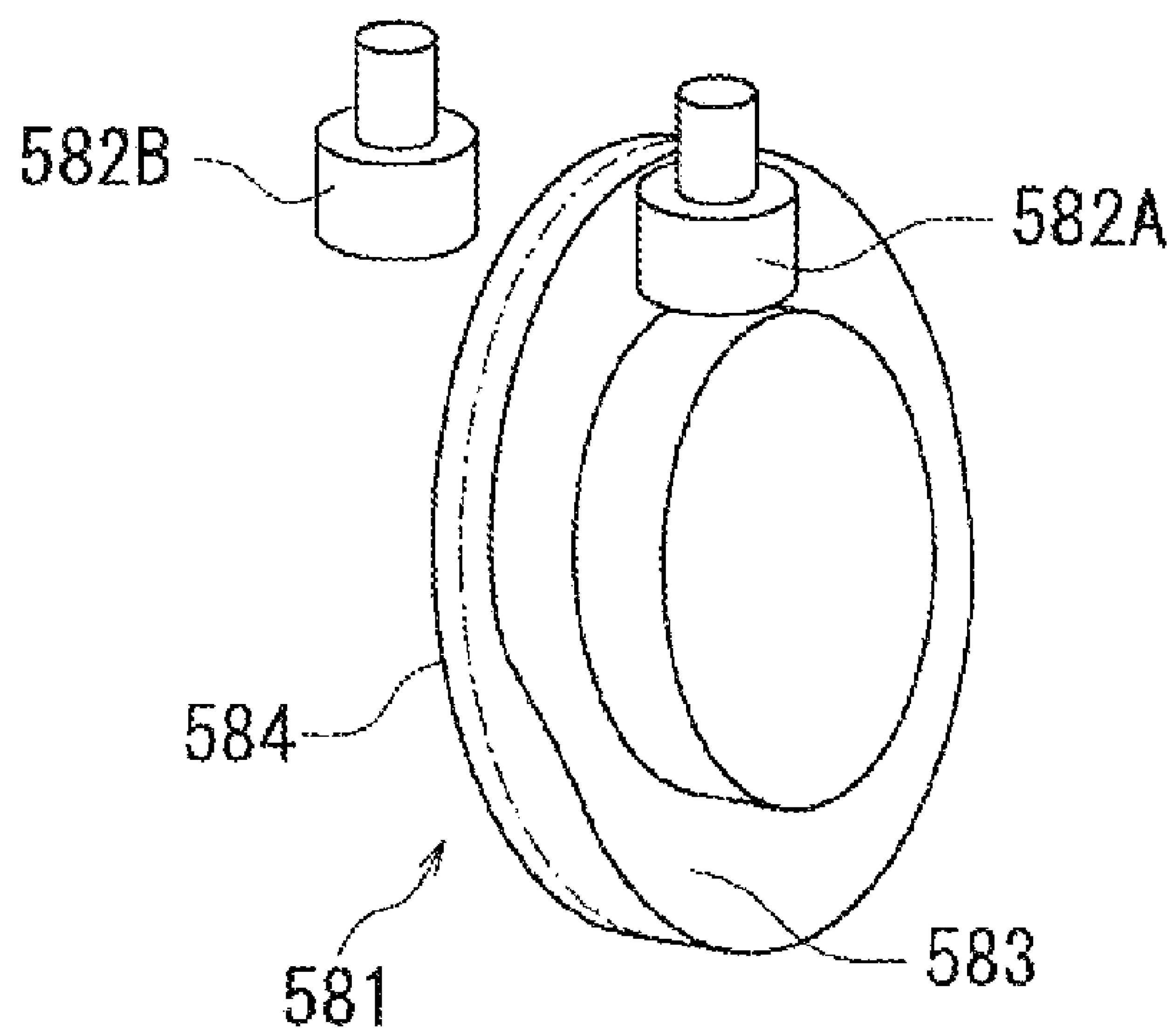


FIG. 12B

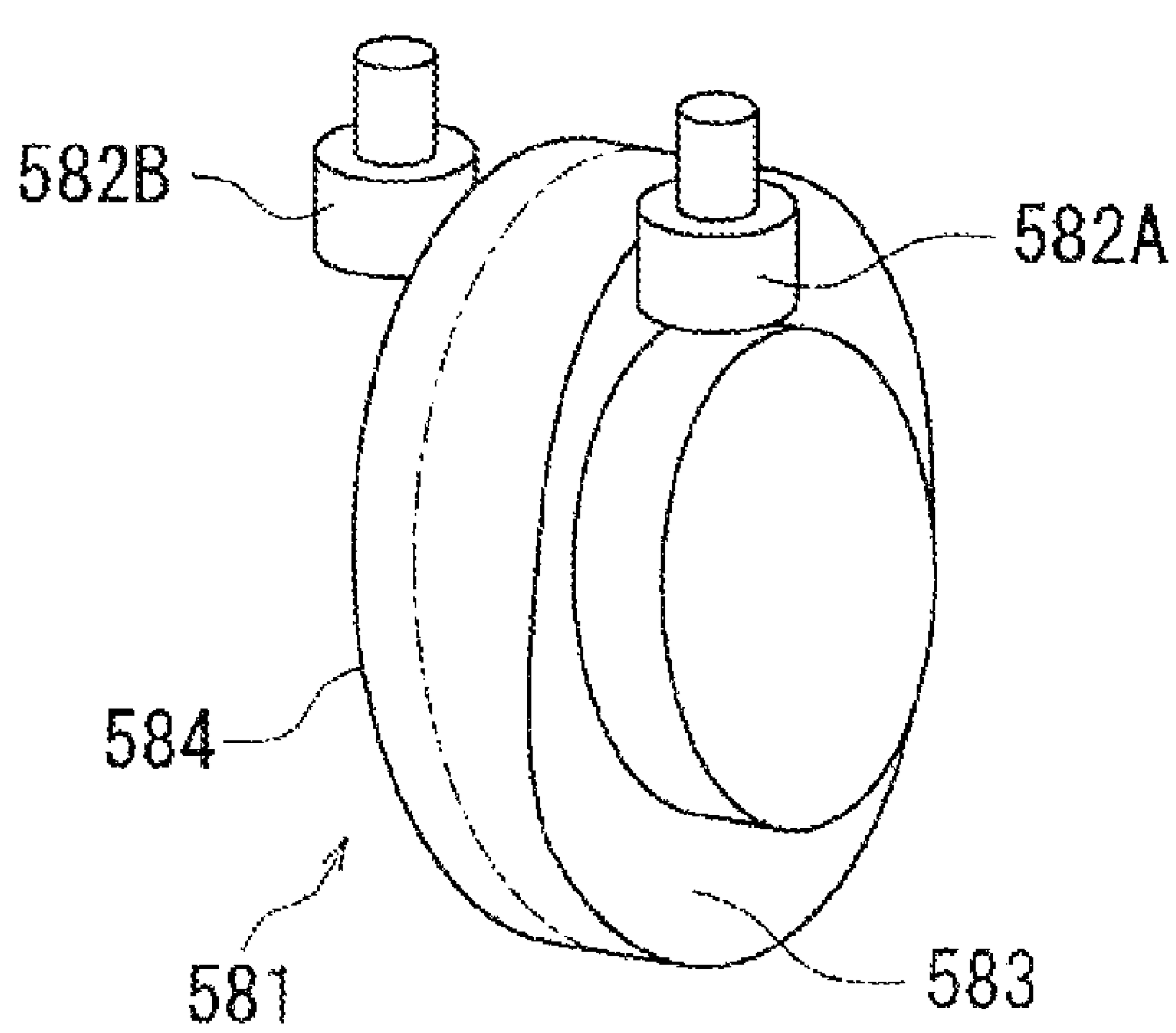


FIG. 12C

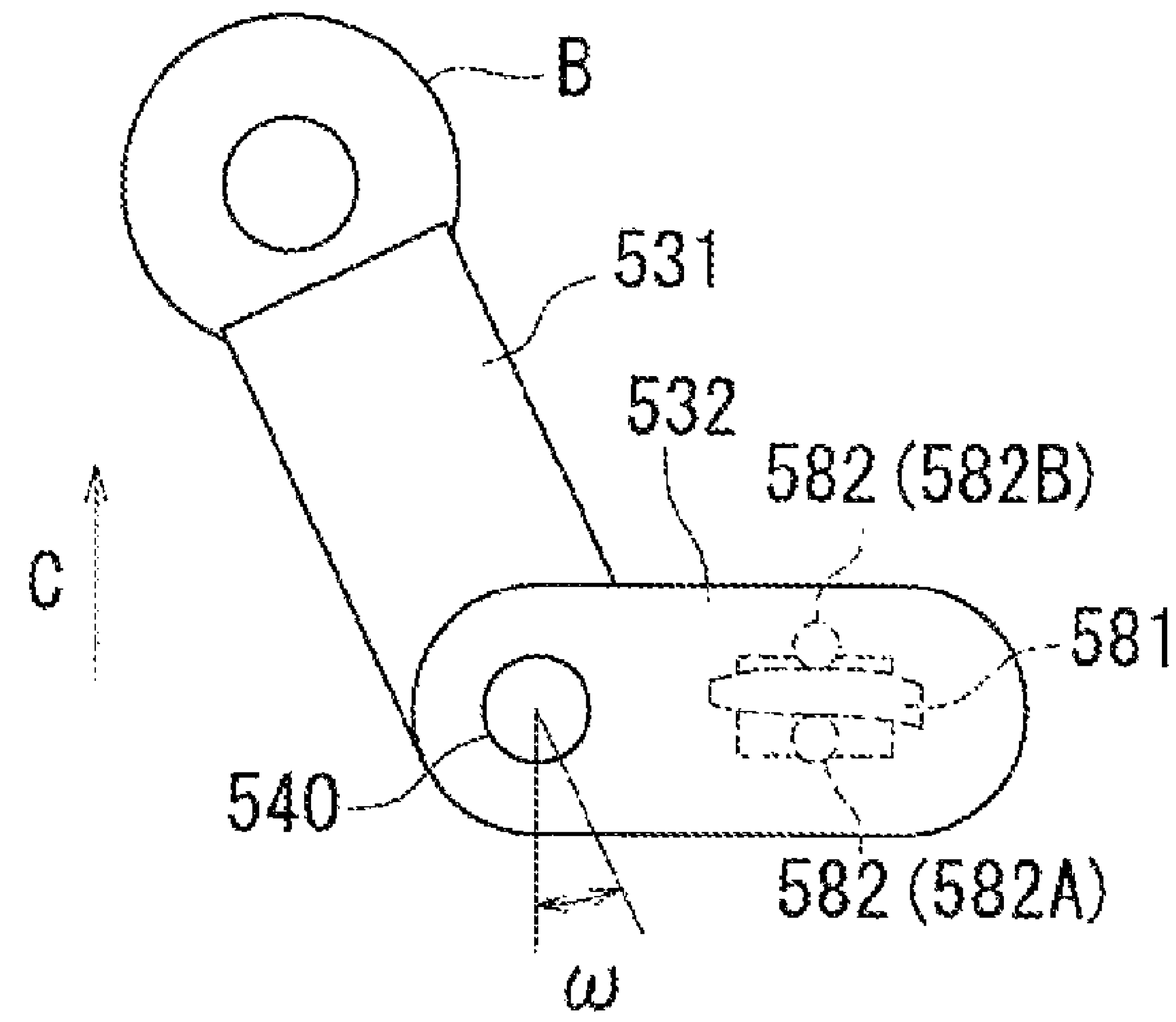


FIG. 13A

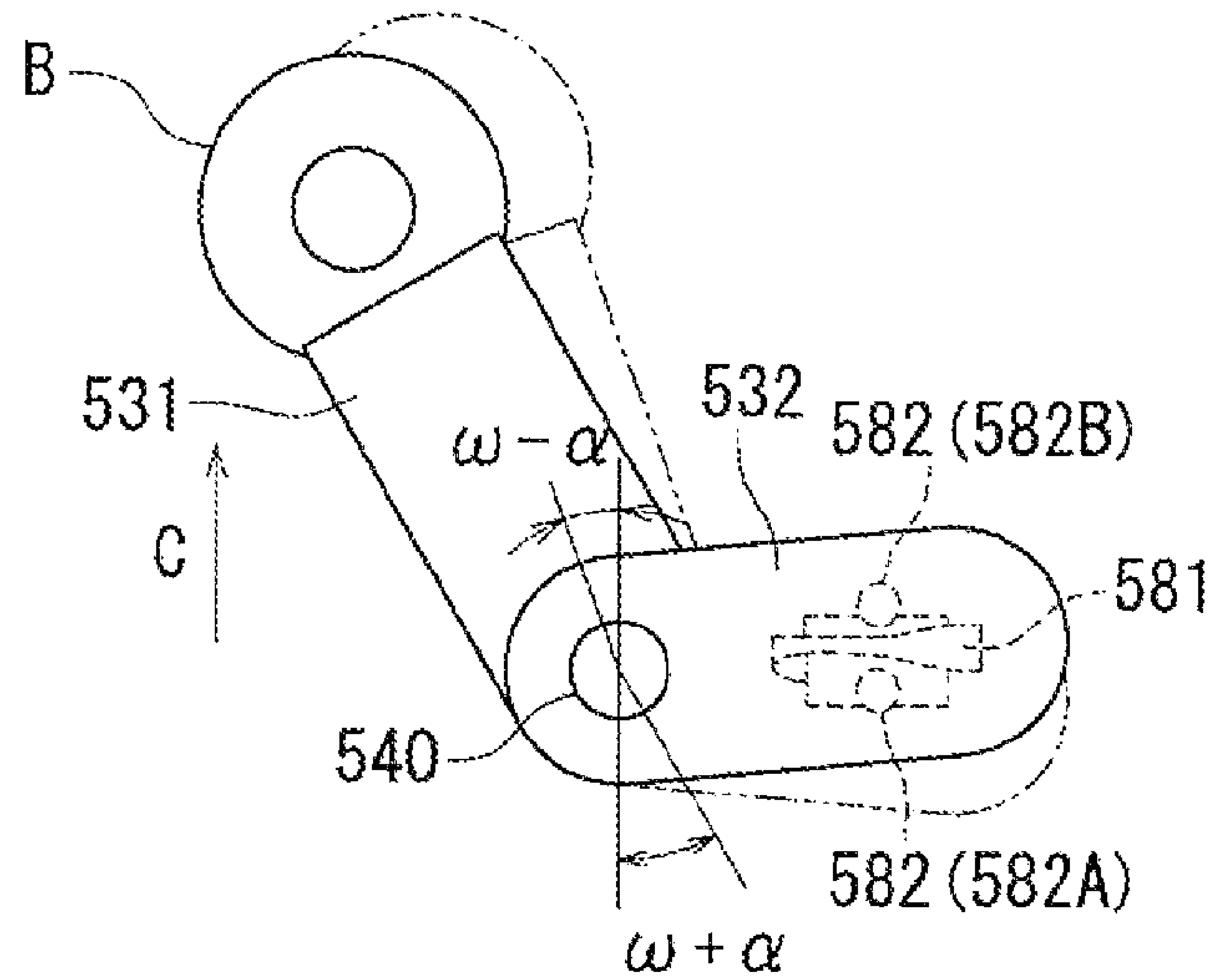


FIG. 13B

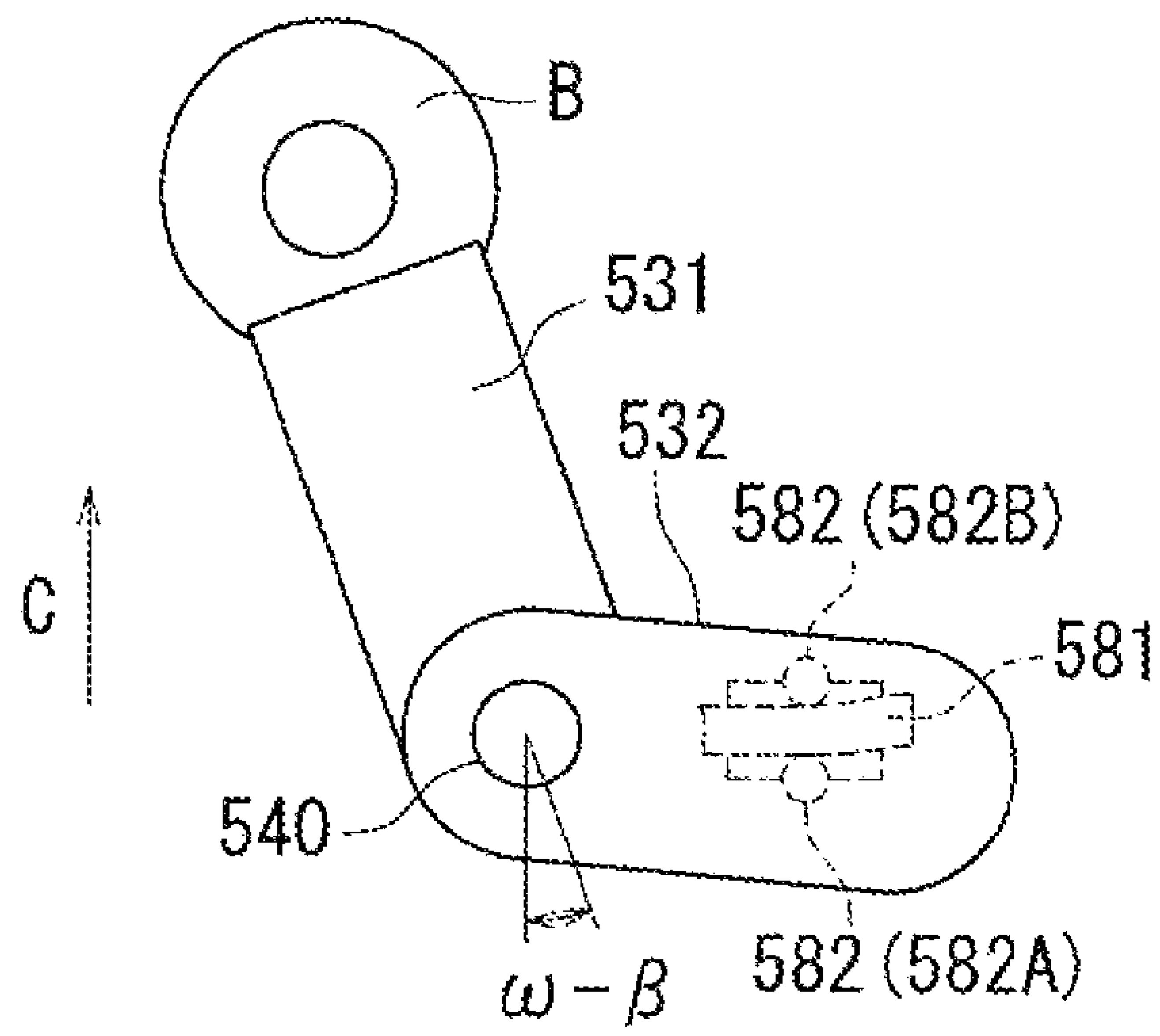


FIG. 13C

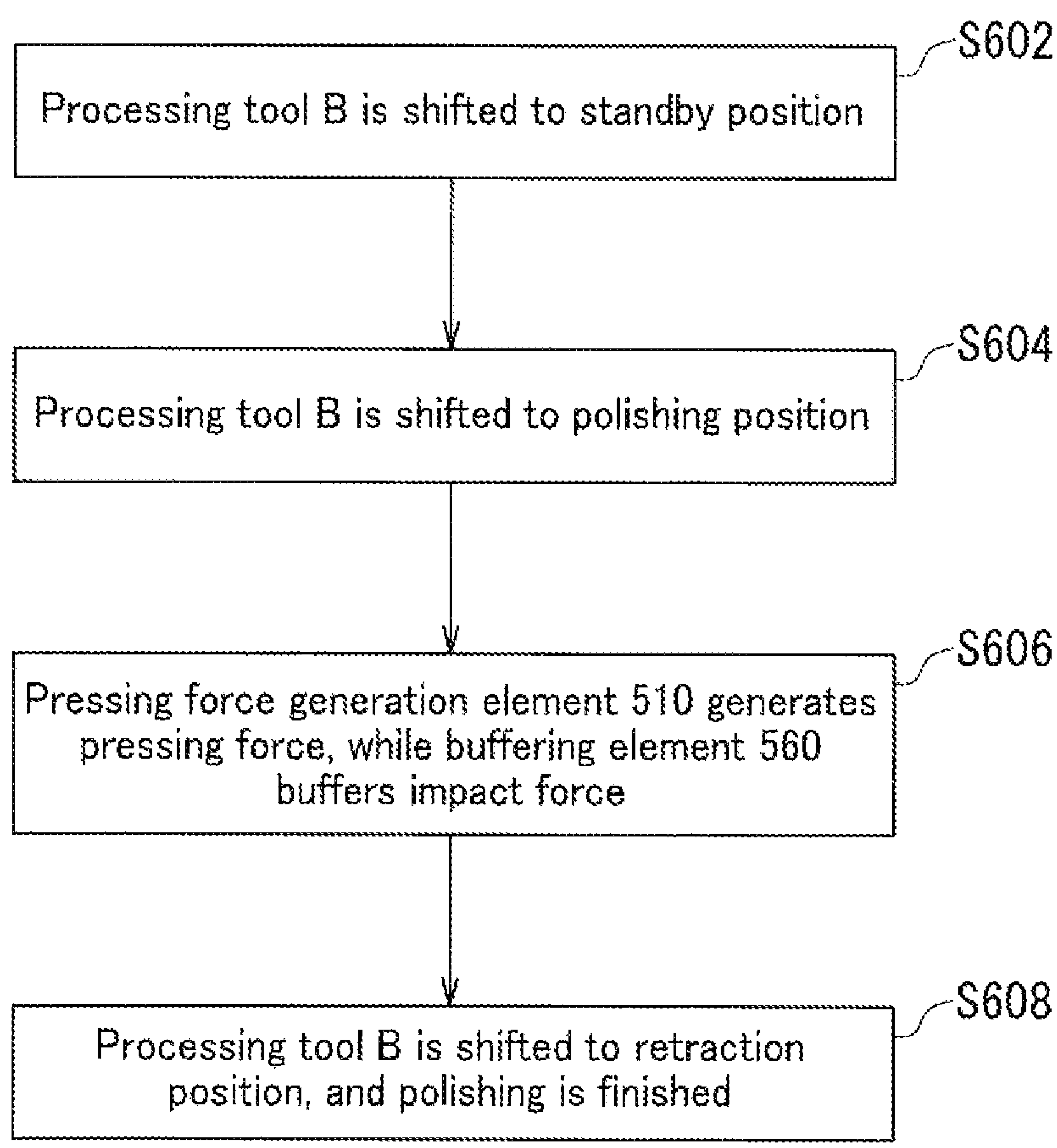

S602
Processing tool B is shifted to standby position
S604
Processing tool B is shifted to polishing position
S606
Pressing force generation element 510 generates pressing force, while buffering element 560 buffers impact force
S608
Processing tool B is shifted to retraction position, and polishing is finished

FIG. 14

GLASS SHEET PROCESSING APPARATUS AND GLASS SHEET PRODUCING METHOD

TECHNICAL FIELD

The present invention relates to glass sheet processing apparatuses for processing an edge surface of a glass sheet using a processing tool and glass sheet producing methods for producing a glass sheet.

BACKGROUND ART

In the field of glass sheets, glass sheets have been increased in size for improvement in efficiency of production of liquid crystal displays and increase in size of liquid crystal displays. A glass sheet increased in size can yield more glass substrates and thus improve production efficiency as well as allow production of glass substrates compatible with large-sized liquid crystal displays.

If a glass sheet has a flaw in a selvage part thereof, the flaw may develop into a crack or the like in the glass sheet. Selvage parts of a glass sheet are therefore chamfered. Furthermore, in order to increase throughput per unit time and lower the production cost, the speed of conveying (speed of processing) a glass sheet is increased.

By observing an edge surface of a glass sheet subjected to the chamfering through a microscope, fine projections and recesses can be found on the edge surface of the glass sheet. Such a glass sheet may have a chip or a crack in a following process (process by a customer), and therefore the edge surface of the glass sheet is polished into an even surface. However, in order to polish the edge surface of the glass sheet into an even surface, an area of the glass sheet reserved for the polishing needs to be set larger. Accordingly, the polishing time is increased, and it is difficult to further increase the glass sheet conveyance speed (processing speed). Besides, when an edge surface of an enlarged and thinned glass sheet is polished, a counter force to the processing force from a grinding or polishing tool to the glass sheet (grinding resistance or polishing resistance) strongly acts, causing a chip or a crack in the edge surface of the glass sheet.

Various methods for processing an edge surface of a glass sheet having microscopic projections and recesses on the edge surface of the glass sheet have been invented (Patent Literatures 1 to 3).

CITATION LIST

Patent Literature

[PTL 1] Japanese Patent Application Laid-Open Publication No. 2000-176804

[PTL 2] Japanese Patent Application Laid-Open Publication No. 2004-167633

[PTL 3] Japanese Patent Application Laid-Open Publication No. 2007-500605

SUMMARY OF INVENTION

Technical Problem

However, conventional processing methods have a limitation in increasing the glass sheet conveyance speed (processing speed). If the speed is increased, for example, a processing tool is flicked off the edge surface of the glass sheet by an impact force generated because of the presence of the microscopic projections and recesses on the edge surface of the glass sheet A (an impact force that the edge surface of the glass sheet exerts on the processing tool (grinding stone)). It is therefore difficult to increase the conveyance speed (processing speed) to a desired processing speed.

In view of the above-described problem, the present invention has been made to provide a glass sheet processing apparatus and a glass sheet producing method capable of preventing a processing tool used therein from being flicked off an edge surface of a glass sheet and capable of processing the edge surface of the glass sheet at a high conveyance speed (processing speed).

Solution to Problem

A glass sheet processing apparatus according to the present invention processes an edge surface of a glass sheet using a processing tool and includes: a pressing force generation element configured to generate a pressing force that the processing tool exerts on the edge surface of the glass sheet; and a buffering element configured to buffer an impact force that the edge surface of the glass sheet exerts on the processing tool.

In the glass sheet processing apparatus according to the present invention, preferably, the buffering element buffers only a first force that the edge surface of the glass sheet exerts on the processing tool without buffering a second force that the processing tool exerts on the edge surface of the glass sheet.

Preferably, the glass sheet processing apparatus according to the present invention further includes a position control section configured to control the processing tool such that it is shifted in sequence among a standby position, a polishing position, and a retraction position, wherein the standby position is where the processing tool is on standby for contact with the edge surface of the glass sheet, the polishing position is where the processing tool is in contact with the edge surface of the glass sheet and is polishing the edge surface, and the retraction position is where the processing tool has been retracted in a direction to separate the processing tool from the edge surface of the glass sheet beyond the standby position.

In the glass sheet processing apparatus according to the present invention, preferably, the buffering element is a dashpot.

In the glass sheet processing apparatus according to the present invention, preferably, the dashpot includes water as a working fluid.

In the glass sheet processing apparatus according to the present invention, preferably, the dashpot includes a piston mechanism, and the piston mechanism has a non-return valve to be closed to an action of the impact force.

Preferably, the glass sheet processing apparatus according to the present invention includes a rotary arm member and a support shaft member, wherein the processing tool is connected with the rotary arm member, the rotary arm member is rotatably connected with the support shaft member, and the pressing force generation element generates the pressing force by applying a couple of forces to the arm member.

In the glass sheet processing apparatus according to the present invention, preferably, the position control section includes a cam member to be rotationally driven and a cam follower to be driven by the rotation of the cam member, the rotary arm member operates in conjunction with the cam follower, the cam follower is displaced relative to the cam member to apply a couple of forces to the rotary arm member, and the processing tool is shifted to the standby position, the polishing position, or the retraction position in response to the application of the couple of forces to the rotary arm member.

In the glass sheet processing apparatus according to the present invention, preferably, the cam follower includes a first cam follower and a second cam follower configured to be movable while maintaining a predetermined gap therebetween; the cam member is a cylindrical end cam having, on one side, a first cam surface capable of being brought into contact with the first cam follower and, on the other side, a second cam surface capable of being brought into contact with the second cam follower; the processing tool is shifted in sequence among the standby position, the polishing position, and the retraction position by change in the position and state of contact between the first cam surface and the first cam follower, and the position and state of contact between the second cam surface and the second cam follower in conjunction with the rotation of the cam member; the rotary arm is in a locked state, in which it is non-rotatable, in the standby position and the retraction position; and the rotary arm is in a free state, in which it is rotatable, in the processing position.

In the glass sheet processing apparatus according to the present invention, preferably, the processing tool is shifted to the standby position when the cam member is rotated by a first rotation phase, the processing tool is shifted to the polishing position when the cam member is rotated by a second rotation phase, the processing tool is shifted to the retraction position when the cam member is rotated by a third rotation phase, a width of the cam member with respect to a portion thereof that comes between the first cam follower and the second cam follower in the case of the first rotation phase and the third rotation phase is equal to the gap between the first cam follower and the second cam follower, the width of the cam member with respect to a portion thereof that comes between the first cam follower and the second cam follower in the case of the second rotation phase is smaller than the gap between the first cam follower and the second cam follower, and the position of the first cam surface in the case of the third rotation phase is offset toward one side in an axial direction of the cam member by a predetermined distance from the position of the first cam surface in the case of the first rotation phase.

Preferably, the glass sheet processing apparatus according to the present invention includes a slide member and a slide rail member, wherein the processing tool is connected with the slide member, and the slide member is connected with the slide rail member in a linearly slidable manner; and the pressing force generation element generates the pressing force by pressing the slide member.

In the glass sheet processing apparatus according to the present invention, preferably, the buffering element includes a Scott Russel linkage mechanism configured to convert a direction in which the impact force acts from the horizontal direction into the vertical direction.

A glass sheet processing apparatus according to the present invention processes an edge surface of a glass sheet using a processing tool, including: a pressing force generation element configured to generate a pressing force that the processing tool exerts on the edge surface of the glass sheet; and a position control section configured to control the processing tool such that it is shifted in sequence among a standby position, a polishing position, and a retraction position, wherein the standby position is where the processing tool is on standby for contact with the edge surface of the glass sheet, the polishing position is where the processing tool is in contact with the edge surface of the glass sheet and is polishing the edge surface, and the retraction position is where the processing tool has been retracted in a direction to separate the processing tool from the edge surface of the glass sheet beyond the standby position.

A glass sheet producing method according to the present invention is a glass sheet producing method for producing a glass sheet having a processed edge surface by processing the edge surface of the glass sheet using a processing tool, including generating a pressing force that the processing tool exerts on the edge surface of the glass sheet while buffering an impact force that the edge surface of the glass sheet exerts on the processing tool.

A glass sheet producing method according to the present invention is a glass sheet producing method for producing a glass sheet having a processed edge surface by processing the edge surface of the glass sheet using a processing tool, including controlling the processing tool such that it is shifted in sequence among a standby position, a polishing position, and a retraction position.

Advantageous Effects of Invention

According to the glass sheet processing apparatus and the glass sheet producing method of the present invention, it is possible to buffer an impact force that an edge surface of a glass sheet exerts on a processing tool. It is therefore possible to prevent the processing tool from being flicked off the edge surface of the glass sheet by the impact force on the glass sheet that is increased with the increase in the glass sheet conveyance speed. As a result, the conveyance speed in the glass sheet production can be increased, and the quantity of glass sheets that can be conveyed to a following process can be increased.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic top view of a glass sheet processing apparatus **100** according to an embodiment of the present invention.

FIG. **2** is a schematic side view of a swivel type glass sheet processing apparatus **200** according to an embodiment of the present invention.

FIG. **3** is a schematic side view of a linear slide type glass sheet processing apparatus **300** according to an embodiment of the present invention.

FIG. **4** is a schematic illustration of a buffering element **120** according to the embodiment of the present invention.

FIG. **5** is a schematic illustration of the buffering element **120** according to the embodiment of the present invention.

FIG. **6** is a schematic illustration of the buffering element **120** according to the embodiment of the present invention.

FIG. **7** is a flowchart showing a glass sheet producing method using the glass sheet processing apparatus **100** of the present embodiment.

FIG. **8** is a schematic top view showing a manner of polishing an edge surface of a glass sheet A at an angle to a feed direction C.

FIG. **9** is a schematic top view of a glass sheet processing apparatus **500** according to an embodiment of the present invention.

FIG. **10** is a schematic cross sectional view of a position control section **580** as seen from a direction of arrows X-X in FIG. **9**.

FIG. **11** is a diagram showing positions of cam followers **582** according to the rotation phase of a cam member **581**.

FIG. **12**A is a diagram showing a state of the cam member **581** rotated by a first rotation phase. FIG. **12**B is a diagram showing a state of the cam member **581** rotated by a second rotation phase. FIG. **12**C is a diagram showing a state of the cam member **581** rotated by a third rotation phase.

FIG. **13**A is a diagram showing a processing tool B in a standby position. FIG. **13**B is a diagram showing the processing tool B in a polishing position. FIG. **13**C is a diagram showing the processing tool B in a retraction position.

FIG. **14** is a flowchart showing a glass sheet producing method using the glass sheet processing apparatus **500** of the present embodiment.

DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments of a glass sheet processing apparatus and a glass sheet producing method of the present invention will be described with reference to the accompanying drawings. However, the present invention is not limited to the following embodiments.

[Glass Sheet Processing Apparatus (Basic Principle)]

FIG. **1** is a schematic top view of a glass sheet processing apparatus **100** according to an embodiment of the present invention. The glass sheet processing apparatus **100** processes an edge surface of a glass sheet A using a processing tool B. The glass sheet processing apparatus **100** includes a pressing force generation element **110** and a buffering element **120**.

The glass sheet A has a shape of a rectangular plate. The glass sheet A has a thickness of 0.05 mm to 10 mm, for example. However, the present invention is not limited thereto. The present invention can be applied to processing of a glass sheet A having a non-rectangular shape (e.g., polygonal shape) and processing of a glass sheet A having a thickness outside the range of 0.05 mm to 10 mm.

The processing tool B processes an edge surface of the glass sheet A. The processing of an edge surface of the glass sheet A can be polishing for evening projections and recesses on a chamfered edge surface. Alternatively, the processing of an edge surface of the glass sheet A can be chamfering of the edge surface of the glass sheet A.

The glass sheet A moves relative to the processing tool B. For example, the processing tool B in a fixed state processes the glass sheet A moving in a glass sheet feed direction C. Alternatively, the processing tool B moving in the feed direction C can process the glass sheet A in a fixed state. The processing tool B is a grinding stone to be driven and rotated, for example. The grinding stone polishes the edge surface of the glass sheet A while being rotated.

The smaller the diameter of the grinding stone is, the smaller the contact area between the glass sheet A and the grinding stone is. Accordingly, the polishing resistance that the grinding stone receives from the glass sheet A is reduced, and the grinding stone can follow the edge surface of the glass sheet A more easily. The polishing resistance can be reduced by reducing the contact area between the glass sheet and the grinding stone. In the embodiment of the present invention, a grinding stone having a diameter of 150 mm can be used.

The pressing force generation element **110** generates a pressing force that the pressing tool B exerts on the edge surface of the glass sheet A. For example, the pressing force generation element **110** may be a low sliding resistance air cylinder. In the embodiment of the present invention, a diaphragm cylinder may be used as the low sliding resistance air cylinder in view of its high responsiveness owing to the low slidability, its long life owing to the absence of a piston, and the like.

The buffering element **120** buffers an impact force that the edge surface of the glass sheet A exerts on the processing tool B. The impact force that the edge surface of the glass sheet A exerts on the processing tool B is generated because of the presence of microscopic projections and recesses on the edge surface of the glass sheet A, for example.

The buffering element **120** functions as a damper element and may be a dashpot, for example. The buffering element **120** in the embodiment of the present invention is an unsealed water dashpot, which can utilize, as a buffering effect, the resistance generated when water passes between a piston and a tube. For example, the buffering element **120** may have a non-return valve thereby to buffer only the first force that the edge surface of the glass sheet A exerts on the processing tool B without buffering the second force that the processing tool B exerts on the edge surface of the glass sheet A (here, the first force acts in the direction indicated by the arrow D, whereas the second force acts in the direction indicated by the arrow E). The buffering element **120** will be described later in detail with reference to FIGS. **4** to **6**.

The glass sheet processing apparatus **100** may further include an arm member **130** and a position control section **180**. The arm member **130** is connected with the processing tool B. The pressing force generation element **110** generates a pressing force against the processing tool B by applying a couple of forces to the arm member **130**. Preferably, the advance direction of the glass sheet A and the arm member **130** form an included angle (angle θ shown in FIG. **1**) of 25° to 35°.

The position control section **180** controls the position of the processing tool B connected with the arm member **130** by controlling the position of the arm member **130**. The position control section **180** includes an inter-cylinder cam and an arm controlling element, for example. The position control section **180** controls the position of the arm member **130** by controlling the rotation of the inter-cylinder cam such that the processing tool B is shifted in sequence among three positions: a standby position (original point), a polishing position (where the arm is free), and a retraction position. The inter-cylinder cam is controlled by the position control section **180**. The position of the processing tool B can be shifted among the three positions including the positions where the arm member **130** is locked (the standby position and the retraction position) within a second, for example. Thus, the arm member **130** can be controlled at a high speed.

The arm member **130** is unlocked at the polishing position. That is, the arm member **130** is in an arm-free state (in an unlocked state). The pressing force generation element **110** applies a couple of forces to the arm member **130** in the arm-free state thereby to generate a pressing force against the processing tool B.

As described with reference to FIG. **1**, the glass sheet processing apparatus **100** of the present invention can buffer the impact force that the edge surface of the glass sheet A exerts on the processing tool B. Thus, it is possible to prevent the processing tool B from being flicked off the edge surface of the glass sheet A because of the presence of the impact force on the glass sheet A, which is increased with the increase in the conveyance speed of the glass sheet A. As a result, the conveyance speed in the glass sheet production can be increased, and the quantity of glass sheets A that can be conveyed to a following process can be increased.

The glass sheet processing apparatus **100** may be of a swivel type or a linear slide type, for example. Hereinafter, a swivel type glass sheet processing apparatus **200** and a linear slide type glass sheet processing apparatus **300** will be described as examples of the glass sheet processing apparatus **100**.

[Swivel Type Glass Sheet Processing Apparatus]

FIG. **2** is a schematic side view of the swivel type glass sheet processing apparatus **200** according to an embodiment of the present invention. The swivel type glass sheet processing apparatus **200** processes the edge surface of the glass sheet A using the processing tool B. The swivel type glass sheet processing apparatus **200** includes a pressing force generation element **210**, a buffering element **220**, a rotary arm member **230**, a support shaft member **240**, a processing tool rotating motor **250**, and a linkage mechanism **260**.

The rotary arm member **230** is connected with the processing tool B. The support shaft member **240** is rotatably connected with the rotary arm member **230**. The pressing force generation element **210** generates a pressing force from the processing tool B toward the glass sheet A by applying a couple of forces to the rotary arm member **230**.

The processing tool rotating motor **250** rotates the processing tool B. A larger output from the processing tool rotating motor **250** can offer a larger resistance against a bound from the edge surface of the glass sheet A, allowing stable processing. However, this requires operation needing monitoring of the motor current value (motor load factor). Accordingly, a motor that clearly shows change in the motor current value and has a capacity not adversely affecting the bound is selected. The output of the processing tool rotating motor **250** may be 1 kW, for example.

The linkage mechanism **260** is configured to communicate the movement of the rotary arm member **230** to the buffering element **220**. The linkage mechanism **260** will be described later in detail with reference to FIGS. **4** to **6**.

The pressing force generation element **210** has a function similar to that of the pressing force generation element **110** described with reference to FIG. **1**. The buffering element **220** has a function similar to that of the buffering element **120** described with reference to FIG. **1**. Accordingly, detailed description thereof will be omitted.

The swivel type glass sheet processing apparatus **200** further includes a glass condition determining section **270** and a position control section **280**. The glass condition determining section **270** determines the glass condition of the glass sheet A introduced into the swivel type glass sheet processing apparatus **200**. For example, the glass condition determining section **270** detects the condition of the glass sheet A by bringing a roller into contact with the edge surface of the glass sheet A introduced into the swivel type glass sheet processing apparatus **200**. The pressing force generation element **210** generates a pressing force against the processing tool B according to the glass condition of the glass sheet A. The position control section **280** controls the position of the rotary arm member **230**. The position control section **280** has a function similar to that of the position control section **180** described with reference to FIG. **1**, and therefore detailed description thereof will be omitted.

[Linear Slide Type Glass Sheet Processing Apparatus]

FIG. **3** is a schematic side view of the linear slide type glass sheet processing apparatus **300** according to an embodiment of the present invention. The linear slide type glass sheet processing apparatus **300** processes the edge surface of the glass sheet A using the processing tool B. The linear slide type glass sheet processing apparatus **300** may include a pressing force generation element **310**, a buffering element **320**, a slide member **330**, a slide rail member **340**, a processing tool rotating motor **350**, and a linkage mechanism **360**.

The slide member **330** is connected with the processing tool B. The slide member **330** is connected with the slide rail member **340** in a linearly slidable manner. The pressing force generation element **310** generates a pressing force from the processing tool B toward the glass sheet A by pressing the slide member **330**. The processing tool rotating motor **350** rotates the processing tool B. The description of the output of the processing tool rotating motor **250** with reference to FIG. **2** applies to the output of the processing tool rotating motor **350**, which may be 1 kW as in the case of the output of the processing tool rotating motor **250**.

The linkage mechanism **360** is configured to communicate the movement of the slide member **330** to the buffering element **320**. The linkage mechanism **360** will be described later in detail with reference to FIGS. **4** to **6**.

The pressing force generation element **310** has a function similar to that of the pressing force generation element **110** described with reference to FIG. **1**. The buffering element **320** has a function similar to that of the buffering element **120** described with reference to FIG. **1**. Accordingly, detailed description thereof will be omitted.

The linear slide type glass sheet processing apparatus **300** further includes a glass condition determining section **370** and a position control section **380**. The glass condition determining section **370** has a function similar to that of the glass condition determining section **270** described with reference to FIG. **2**. The position control section **380** has a function similar to that of the position control section **180** described with reference to FIG. **1**. Accordingly, detailed description thereof will be omitted.

[Buffering Element]

FIGS. **4** to **6** are schematic illustrations of the buffering element **120** according to the embodiment of the present invention. A configuration of the buffering element **120** according to the embodiment of the present invention will be described with reference to FIGS. **4** to **6**. The buffering element **120** in the embodiment of the present invention is an unsealed water dashpot. Specifically, the buffering element **120** includes an orifice plate **410**, a non-return valve **420**, a piston **430**, a chamber **440**, and a working fluid H.

The piston **430** descends and ascends in the vertical direction (direction indicated by the arrow G) according to the movement of the arm member **130**. The chamber **440** is filled with the working fluid H (e.g., water) and accommodates the orifice plate **410** and the non-return valve **420**. The orifice plate **410** is fixed to the piston **430**, and descends and ascends with the descent and ascent of the piston **430**. The orifice plate **410** is a plate having a toroidal shape and configured to measure the flow rate using the difference between the pressures generated at the sides above and below the orifice plate **410**.

The non-return valve **420** is closed to the action of the impact force. For example, the non-return valve **420** is a check valve. The non-return valve **420** can limit the direction of the action of the buffering element **120**. When the processing tool B is shifted toward the edge surface of the glass sheet A, the buffering effect is not produced, so that the movement of the arm member **130** is not affected. When the processing tool B is shifted away from the edge surface of the glass sheet A, the buffering effect is produced, so that the movement of the arm member **130** can be buffered.

The buffering element **120** includes a piston end portion **480**, a coil spring **490**, and a tension spring **495**. The piston end portion **480** is fixed to the piston **430** and accommodated within the chamber **440**. The coil spring **490** is on top of the piston end portion **480**, and the non-return valve **420** is on top of the coil spring **490**. The coil spring **490** is a weak spring for supporting the weight of the non-return valve **420**. One end of the tension spring **495** is fixed to the piston **430**, and the other end of the tension spring **495** is fixed to a fixed wall. The tension spring **495** will be described later in detail.

The buffering element **120** according to the embodiment of the present invention is not limited to the unsealed water dashpot as long as it can buffer the impact force that the edge surface of the glass sheet A exerts on the processing tool B. That is, the buffering element **120** may be a different type of damper element. In the present specification, the non-return valve **420** and the piston **430** function as a piston mechanism.

Description of the configuration of the buffering element **120** according to the embodiment of the present invention will be continued with reference to FIGS. **4** to **6**. The buffering element **120** is provided with the linkage mechanism **260**. The linkage mechanism **260** functions to communicate the movement of the rotary arm member **130** to the buffering element **120**. The linkage mechanism **260** in the embodiment of the present invention is a Scott Russel linkage mechanism, for example. The linkage mechanism **260** includes a first linkage member **450**, a second linkage member **460**, and a fixed shaft **470**.

The first linkage member **450** and the second linkage member **460** are made from an undeformable material. The piston **430**, the first linkage member **450**, the second linkage member **460**, and the fixed shaft **470** are connected together by joints.

The arm member **130** and the first linkage member **450** are connected together by the joint, and the movement of the arm member **130** in the horizontal direction (direction indicated by the arrow F) is communicated to the first linkage member **450**. The first linkage member **450** and the second linkage member **460** are connected together by the joint, and the first linkage member **450** and the piston **430** are connected together by the joint. Accordingly, the movement of the first linkage member **450** is communicated to the piston **430**. The second linkage member **460** and the fixed shaft **470** are connected together by the joint. The fixed shaft **470** is fixed relative to the chamber **440** and guides the descent and ascent of the piston **430** in the vertical direction (direction indicated by the arrow G).

The tension spring **495** balances the weight of the linkage. The weight of the linkage is a total weight of the orifice plate **410**, the non-return valve **420**, the piston **430**, the first linkage member **450**, the second linkage member **460**, the piston end portion **480**, and the coil spring **490**. Where the chamber **440** has a vertically-long shape (i.e., shape to move the piston **430** in the vertical direction (direction indicated by the arrow G)), the gravity needs to be taken into consideration. That is, the arm member **130** is always urged to move toward the edge surface of the glass sheet A by the pressing force against the arm member **130** toward the edge surface of the glass sheet A. However, the center of gravity of the linkage moves with the movement of the linkage between a point where the arm member **130** is closest to the chamber **440** and a point where the arm member **130** is farthest from the chamber **440**. As a result, the weight of the linkage is added to or reduced from the pressing force, preventing the pressing force from being constant in some cases.

The tension spring **495** is therefore introduced on the assumption that the pressing force has a proportional relationship with the position of the arm member **130** between the point where the arm member **130** is closest to the chamber **440** and the point where the arm member **130** is farthest from the chamber **440**. As a result, the tension spring **495** supports the linkage and balances the weight of the linkage such that the weight of the linkage does not affect the pressing force wherever the arm member **130** is positioned.

The operation of the buffering element **120** will be further described with reference to FIGS. **4** to **6**. FIG. **4** shows a state A. The arm member **130** is in the position farthest from the chamber **440**. The non-return valve **420** blocks a part of an opening of the orifice plate **410**.

FIG. **5** shows a state B. In the case of the state B, the processing tool B is in contact with fine projections on the edge surface of the glass sheet A. As a result, the arm member **130** is in the position closer to the linkage mechanism **260** in the state B than in the state A.

The piston **430** descends in the vertical direction when the arm member **130** presses the first linkage member **450** toward the linkage mechanism **260**. Since the piston end portion **480** descends lower in the vertical direction in the state B than in the state A, the orifice plate **410** presses the non-return valve **420** downward in the vertical direction to keep the non-return valve **420** closed (i.e., the non-return valve **420** keeps on blocking a part of the opening of the orifice plate **410**). The orifice plate **410** and the non-return valve **420** descend in the vertical direction as the state shifts from A to B, and the working fluid H below the position of the orifice plate **410** moves upward through a gap between the orifice plate **410** and the inner wall of the chamber **440** to an area above the orifice plate **410**. That is, when the impact force from the edge surface of the glass sheet A acts on the processing tool B because of the presence of the fine projections on the edge surface of the glass sheet A, the buffering element **120** buffers the impact force while the pressing force generation element **110** generates the pressing force that the processing tool B exerts on the edge surface of the glass sheet A.

FIG. **6** shows a state C. The pressing force generation element **110** continues to generate the pressing force against the arm member **130** even after time from the end of the state B, and thus the arm member **130** is in a position farther from the linkage mechanism **260** in the state C than in the state B. Since the pressing force generation element **110** continues to generate the pressing force against the arm member **130**, the arm member **130** pulls the first linkage member **450** away from the chamber **440**. As a result, the orifice plate **410** and the piston end portion **480** ascend more in the vertical direction in the state C than in the state B, and the non-return valve **420** compresses the coil spring **490** downward in the vertical direction. Consequently, the non-return valve **420** opens (i.e., the part of the opening of the orifice plate **410**, which was blocked by the non-return valve **420**, opens).

As described above, the orifice plate **410** and the piston end portion **480** ascend more in the vertical direction in the state C than in the state B as the state shifts from B to C. Once the non-return valve **420** opens, the working fluid H above the position of the orifice plate **410** moves downward through the opening of the orifice plate **410** to an area below the orifice plate **410**.

The arm member **130** is in a position farthest from the linkage mechanism **260** in the case of the state A out of the operation states (states A to C) of the buffering element **120**. Once the processing tool B is in contact with the fine projections on the edge surface of the glass sheet A, the state shifts from A to B, and then shifts from B to C. Since the orifice plate **410** is fixed to the piston **430**, and the piston end portion **480** is also fixed to the piston **430**, the gap between the orifice plate **410** and the piston end portion **480** is constant. Accordingly, the non-return valve **420** moves between the orifice plate **410** and the piston end portion **480** under the force of the coil spring **490**.

When the processing tool B is shifted away from the edge surface of the glass sheet A, the orifice plate **410** presses the non-return valve **420** downward in the vertical direction. Since the non-return valve **420** is kept closed, the buffering element **120** produces the buffering effect, so that the movement of the arm member **130** can be buffered. Meanwhile, since the pressing force generation element **110** continues to generate the pressing force against the arm member **130**, the processing tool B is shifted toward the edge surface of the glass sheet A, and the non-return valve **420** compresses the coil spring **490** downward in the vertical direction. As a result, the non-return valve **420** opens, and the buffering effect by the buffering element **120** is eliminated. The pressing force generation element **110** generates the pressing force that the processing tool B exerts on the edge surface of the glass sheet A to keep the processing tool B in contact with the edge surface of the glass sheet A.

As described with reference to FIGS. **4** to **6**, the movement of the arm member **130** in the horizontal direction (direction indicated by the arrow F) can be converted into the descent and ascent of the piston **430** in the vertical direction (direction indicated by the arrow G) when the buffering element **120** according to the embodiment of the present invention includes a Scott Russel linkage mechanism as the linkage mechanism **260**. As a result, a water dashpot having a vertically-long shape can be used as the buffering element **120**. Consequently, the need of using a sealing structure such as an O-ring for preventing leakage of the working fluid H can be eliminated, and the influence of the seal resistance can be ignored.

It should be noted that the present invention is not limited to the configuration in which the buffering element **120** includes a Scott Russel linkage mechanism as the linkage mechanism **260**. The effect of the present invention can be obtained even when the buffering element **120** does not include the Scott Russel linkage mechanism as long as the buffering element **120** buffers the impact force that the edge surface of the glass sheet A exerts on the processing tool B.

The operation of the buffering element **120** has been described with reference to FIGS. **4** to **6** so far. The buffering element **220** described with reference to FIG. **2** and the buffering element **320** described with reference to FIG. **3** operate in the same manner as the buffering element **120**. Accordingly, detailed description thereof will be omitted.

FIG. **7** is a flowchart showing a glass sheet producing method using the glass sheet processing apparatus **100** of the present embodiment. Hereinafter, the glass sheet producing method using the glass sheet processing apparatus **100** will be described. According to the glass sheet producing method of the present invention, the glass sheet A can be produced by processing the edge surface of the glass sheet A using the processing tool B. The glass sheet producing method is achieved through Steps S**202** to S**206**. Step S**204** functions as a step of buffering the impact force while generating the pressing force.

Step S**202**: The processing tool B is shifted to the standby position (original point).

Step S**204**: The pressing force generation element **110** generates the pressing force that the processing tool B exerts on the edge surface of the glass sheet A. The processing tool B is brought into contact with the edge surface of the glass sheet A, whereupon the polishing of the glass sheet A is started. The processing tool B is brought into contact with the edge surface of the glass sheet A such that the arm member **130** forms an angle of 25° to 35° to the advance direction of the glass sheet A.

When the impact force from the edge surface of the glass sheet A acts on the processing tool B because of the presence of the fine projections on the edge surface of the glass sheet A, the buffering element **120** buffers the impact force while the pressing force generation element **110** generates the pressing force that the processing tool B exerts on the edge surface of the glass sheet A.

Step S**206**: The arm member **130** separates the processing tool B from the edge surface of the glass sheet A and shifts the processing tool B to the retraction position, whereupon the polishing is finished. The retraction position coincides with the standby position (original point) in the present embodiment.

According to the glass sheet processing apparatus and the glass sheet producing method of the present embodiment, as described with reference to FIGS. **1** to **7**, the impact force that the edge surface of the glass sheet A exerts on the processing tool B can be buffered while the pressing force that the processing tool B exerts on the edge surface of the glass sheet A is generated. Thus, the processing tool B can be prevented from being flicked off the edge surface of the glass sheet A by the impact force on the processing tool B that is increased with the increase in the conveyance speed of the glass sheet A. As a result, the conveyance speed in the glass sheet production can be increased, and the quantity of glass sheets A that can be conveyed to a following process can be increased.

In the embodiment described with reference to FIG. **1**, the processing tool B polishes the edge surface of the glass sheet A in parallel with the feed direction C. Alternatively, the processing tool B may polish the edge surface of the glass sheet A at an angle to the feed direction C. FIG. **8** is a schematic top view showing the manner of polishing the edge surface of the glass sheet A at an angle to the feed direction C. In FIG. **8**, a trailing end A**2** of the edge surface of the glass sheet A deviates from an orbit R thereof in the case of conveyance parallel to the feed direction to a side closer to the processing tool B. When the edge surface of the glass sheet A is polished while taking the posture as shown in FIG. **8**, and the processing tool B is returned from a polishing end position (as indicated by solid lines) to the standby position (as indicated by dashed and double dotted lines), the processing tool B may scratch the edge surface of the glass sheet A, and therefore the edge surface of the glass sheet A or the processing tool B may be damaged. It is therefore necessary to first retract the processing tool B in a direction to separate the processing tool B from the edge surface of the glass sheet A once the polishing is finished, and then return it to the standby position. That is, the processing tool B needs to be controlled such that it is shifted in sequence among the three positions: the standby position, the polishing position, and the retraction position where the processing tool B is retracted in the separating direction beyond the standby position.

FIG. **9** is a schematic top view of a glass sheet processing apparatus **500** according to an embodiment of the present invention. The processing tool B in the glass sheet processing apparatus **500** of the present embodiment is controlled such that it is shifted in sequence among the three positions: the standby position, the polishing position, and the retraction position where the processing tool B is retracted in the separating direction beyond the standby position. Hereinafter, the glass sheet processing apparatus **500** of the present embodiment will be described with reference to FIG. **9**.

The glass sheet processing apparatus **500** processes the edge surface of the glass sheet A using the processing tool B. The glass sheet processing apparatus **500** includes a pressing force generation element **510**, a buffering element **520**, a rotary arm member **530**, a support shaft member **540**, a processing tool rotating motor (not shown), a linkage mechanism (not shown), a glass condition determining section (not shown), and a position control section **580**. The pressing force generation element **510**, the buffering element **520**, the rotary arm member **530**, the support shaft member **540**, the processing tool rotating motor, the linkage mechanism, and the glass condition determining section are as described in the embodiment shown in FIG. **2**, and therefore description thereof will be omitted.

The rotary arm member **530** is connected with the processing tool B. The support shaft member **540** is rotatably connected with the rotary arm member **530**. The processing tool B is shifted in a direction to press the processing tool B against the edge surface of the glass sheet A (direction indicated by the arrow **K1** in FIG. **9**: pressing direction) or in a direction to separate the processing tool B from the edge surface of the glass sheet A (direction indicated by the arrow **K2** in FIG. **9**: separating direction) by the rotation of the rotary arm member **530**.

The rotary arm member **530** in the present embodiment has a first arm portion **531** and a second arm portion **532**. One end of the first arm portion **531** is connected with the processing tool B. The other end of the first arm portion **531** and one end of the second arm portion **532** are connected with each other. The support shaft member **540** is connected with a region where the first arm portion **531** and the second arm portion **532** are connected. The pressing force generation element **510** generates the pressing force from the processing tool B toward the glass sheet A by applying a couple of forces to the first arm portion **531** of the rotary arm member **530**.

The position control section **580** controls the position of the rotary arm member **530** such that the processing tool B is shifted in sequence among the standby position, the polishing position, and the retraction position. The standby position is where the processing tool B is on standby for the contact with the edge surface of the glass sheet A. The polishing position is where the processing tool B is in contact with the edge surface of the glass sheet A and is polishing the edge surface. The retraction position is where the processing tool B has been retracted in the separating direction beyond the standby position. The position control section **580** in the embodiment of the present invention includes a cam member **581** (inter-cylinder cam) and cam followers **582** (arm controlling elements).

The cam member **581** is rotationally driven by a cam member rotating motor **585**. The cam member rotating motor **585** in the present embodiment is a servomotor, for example. The cam member **581** is rotated by the cam member rotating motor **585** at a predetermined speed and by a predetermined phase (angle). The servomotor may be provided with a reducer.

The cam followers **582** are connected with the rotary arm member **530** to coordinate with the rotary arm member **530**. The cam followers **582** in the present embodiment are connected with the second arm portion **532**. The cam followers **582** are driven by the rotation of the cam member **581** and displaced in the axial direction (direction indicated by the arrow **J1** or direction indicated by the arrow **J2**) of the cam member **581**. The rotary arm member **530** rotates in conjunction with the cam followers **582** being displaced in the direction indicated by the arrow **J1** to shift the processing tool B in the pressing direction (direction indicated by the arrow **K1**). Or, the rotary arm member **530** rotates in conjunction with the cam followers **582** being displaced in the direction indicated by the arrow **J2** to shift the processing tool B in the separating direction (direction indicated by the arrow **K2**).

FIG. **10** is a schematic cross sectional view of the position control section **580** as seen from a direction of arrows X-X in FIG. **9**. Description of the position control section **580** will be continued with reference to FIGS. **9** and **10**. Specifically, the position control section **580** has the two cam followers **582** (hereinafter, may be referred to as a first cam follower **582**A and a second cam follower **582**B). The first cam follower **582**A and the second cam follower **582**B are disposed on the second arm portion **532** with a predetermined gap therebetween, and are movable with the second arm portion **532** while maintaining the predetermined gap.

The cam member **581** is a cylindrical end cam having a first cam surface **583** and a second cam surface **584** opposite to the first cam surface **583**. The first cam surface **583** is on one side of the rotational axis of the cam member **581**. The first cam surface **583** can be brought into contact with the first cam follower **582**A during the time when the cam member **581** is rotating. The second cam surface **584** is on the other side of the rotational axis of the cam member **581**. The second cam surface **584** can be brought into contact with the second cam follower **582**B during the time when the cam member **581** is rotating.

FIG. **11** is a diagram showing positions of the cam followers **582** according to the rotation phase of the cam member **581**. FIGS. **12**A to **12**C are schematic perspective views of the position control section **580**. FIG. **12**A shows a state of the cam member **581** rotated by a first rotation phase. FIG. **12**B shows a state of the cam member **581** rotated by a second rotation phase. FIG. **12**C shows a state of the cam member **581** rotated by a third rotation phase. FIGS. **13**A to **13**C are schematic top views showing the position of the processing tool B being shifted with the displacement of the cam followers **582**. FIG. **13**A shows the processing tool B in the standby position. FIG. **13**B shows the processing tool B in the polishing position. FIG. **13**C shows the processing tool B in the retraction position. Hereinafter, the shape of the cam member **581**, and the relationship between the rotation of the cam member **581** and the position of the processing tool B will be described with reference to FIGS. **11**, **12**A to **12**C, and **13**A to **13**C.

The position and state of the contact between the first cam surface **583** and the first cam follower **582**A, and the position and state of the contact between the second cam surface **584** and the second cam follower **582**B change in conjunction with the rotation of the cam member **581**. Such change shifts the processing tool B in sequence among the standby position, the polishing position, and the retraction position. Specifically, the cam member **581** is driven by the cam member rotating motor **585** and rotated by the first rotation phase (0°), the second rotation phase (120°), and the third rotation phase (240°) in sequence. The rotation of the cam member **581** by the first rotation phase shifts the processing tool B to the standby position. The rotation of the cam member **581** by the second rotation phase shifts the processing tool B to the processing position. The rotation of the cam member **581** by the third rotation phase shifts the processing tool B to the retraction position.

[Standby Position]

The width of the cam member **581** with respect to a portion thereof that comes between the first cam follower **582**A and the second cam follower **582**B in the case of the first rotation phase is equal to the gap between the first cam follower **582**A and the second cam follower **582**B. The first cam follower **582**A is in contact with the first cam surface **583**, and the second cam follower **582**B is in contact with the second cam surface **584**. Accordingly, the displacement of the first cam follower **582**A and the second cam follower **582**B in the direction indicated by the arrow **J1** (direction of the displacement of the cam followers for shifting the processing tool B in the pressing direction) or in the direction indicated by the arrow **J2** (direction of the displacement of the cam followers for shifting the processing tool B in the separating direction) is restricted. Thus, the rotary arm member **530** is put in a locked state where it is non-rotatable. Accordingly, in the case of the first rotation phase, the processing tool B is in a predetermined position (the standby position in the present embodiment) where it does not shift. As shown in FIG. **13**A, an included angle ω formed by the feed direction C and the longitudinal direction of the first arm portion **531** of the rotary arm member **530** is 30°, for example, when the processing tool B is in the standby position.

[Polishing Position]

The width of the cam member **581** with respect to a portion thereof that comes between the first cam follower **582**A and the second cam follower **582**B in the case of the second rotation phase (hereinafter, may be referred to as a second-rotation-phase cam width) is smaller than the gap between the first cam follower **582**A and the second cam follower **582**B. The first cam follower **582**A and the second cam follower **582**B can be freely displaced in the direction indicated by the arrow J1 or in the direction indicated by the arrow J2 within a predetermined distance (distance obtained by subtracting the second-rotation-phase cam width from the gap between the cam followers). Thus, the rotary arm member **530** is put in a free state where it is rotatable.

Accordingly, in the case of the second rotation phase, the displacement of the cam member **581** and the cam member **582** in the direction indicated by the arrow J1 shifts the processing tool B in the pressing direction away from the standby position as shown in FIG. **13**B. When the processing tool B is in a position where it has been shifted maximally in the pressing direction (as indicated by solid lines), the included angle formed by the feed direction C and the longitudinal direction of the first arm portion **531** of the rotary arm member **530** is "ω+α". In addition, the displacement of the cam member **581** and the cam member **582** shifts the processing tool B in the separating direction beyond the standby position. When the processing tool B is in a position where it has been shifted maximally in the separating direction (as indicated by dashed and double dotted lines), the included angle formed by the feed direction C and the longitudinal direction of the first arm portion **531** of the rotary arm member **530** is "ω−α". For example, α is 1°. Herein, α can be adjusted by changing the distance obtained by subtracting the second-rotation-phase cam width from the gap between the cam followers.

[Retraction Position]

The width of the cam member **581** with respect to a portion thereof that comes between the first cam follower **582**A and the second cam follower **582**B in the case of the third rotation phase is equal to the gap between the first cam follower **582**A and the second cam follower **582**B. The first cam follower **582**A is in contact with the first cam surface **583**, and the second cam follower **582**B is in contact with the second cam surface **584**. Accordingly, the displacement of the first cam follower **582**A and the second cam follower **582**B in the directions indicated by the arrows J is restricted. Thus, the rotary arm member **530** is put in a locked state where it is non-rotatable.

The position of the first cam surface **583** (or the second cam surface **584**) in the case of the third rotation phase is offset in the direction indicated by the arrow J2 by a predetermined distance from the position of the first cam surface **583** (or the second cam surface **584**) in the case of the first rotation phase. Accordingly, driven by the cam member **581** rotated by the third rotation phase, the first cam follower **582**A and the second cam follower **582**B are displaced in the direction indicated by the arrow J2 to shift the processing tool B in the separating direction beyond the standby position. As shown in FIG. **13**C, the included angle formed by the feed direction C and the longitudinal direction of the first arm portion **531** of the rotary arm member **530** is "ω−β" when the processing tool B is in the retraction position after having been shifted in the separating direction.

In the present embodiment, β is an angle equal to α. That is, the position of the processing tool B having been shifted maximally in the separating direction (ω−α) coincides with the retraction position (ω−β) of the processing tool B. Herein, β can be adjusted by changing the distance from the position of the first cam surface **583** (or the second cam surface **584**) in the case of the first rotation phase by which the position of the first cam surface **583** (or the second cam surface **584**) in the case of the third rotation phase is offset.

The first cam surface **583** and the second cam surface **584** are formed such that the orbits of the first cam follower **582**A and the second cam follower **582**B in the circumferential direction of the cam member **581** between the first rotation phase and the second rotation phase, and between the second rotation phase and the third rotation phase are represented by constant velocity curves.

The glass sheet processing apparatus **500** of the present embodiment has been described with reference to FIGS. **9** to **13**. According to the present embodiment, the processing tool B is controlled such that it is shifted in sequence among the standby position, the polishing position, and the retraction position. Herein, the retraction position is where the processing tool B has been retracted in the separating direction beyond the standby position. It is therefore possible to first retract the processing tool B in the separating direction, and then return it to the standby position after the completion of the polishing, when the edge surface of the glass sheet A is polished while taking the posture as shown in FIG. **8**. As a result, the processing tool B can be prevented from scratching the edge surface of the glass sheet A, and the glass sheet A or the processing tool B can be prevented from being damaged because of the scratching. According to the present embodiment, the control of the processing tool B to be shifted among the three positions can be achieved by rotating the cam member **581** in increments of 120°. The glass sheet processing apparatus **500** of the present embodiment therefore has a simpler structure and is less likely to cause delay in operation compared with an apparatus that achieves the shifting of a processing tool to the retraction position by a translatory mechanism, which shifts the processing tool back and forth.

Although the first rotation phase is 0°, the second rotation phase is 120°, and the third rotation phase is 240° in the present embodiment, the present invention is not limited thereto. The first rotation phase, the second rotation phase, and the third rotation phase can be determined according to demands in terms of the control of the operation of the processing tool B. In addition, the first cam surface **583** and the second cam surface **584** may be formed such that the orbits of the first cam follower **582**A and the second cam follower **582**B in the circumferential direction of the cam member **581** are represented by straight lines within a range of 5° either side of each of the first rotation phase, the second rotation phase, and the third rotation phase. Consequently, the processing tool B can be shifted to a desired position even if the rotation angle of the cam member **581** is slightly different from the desired angle (0°, 120°, or 240°).

FIG. **14** is a flowchart showing a glass sheet producing method using the glass sheet processing apparatus **500** of the present embodiment. Hereinafter, the glass sheet producing method using the glass sheet processing apparatus **500** will be described with reference to FIGS. **9** to **14**. The glass sheet producing method includes controlling the processing tool B such that it is shifted in sequence among the standby position, the polishing position, and the retraction position. The glass sheet producing method is achieved through Steps S**602** to S**608**.

Step S**602**: The processing tool B is shifted to the standby position. Specifically, the cam member **581** is driven by the cam member rotating motor **585** and rotated by the first rotation phase. The processing tool B is shifted to the standby position in conjunction with the cam member **581** rotated by the first rotation phase. The processing tool B does not move freely in the standby position because the rotary arm member **530** is in the locked state.

Step S**604**: The processing tool B is shifted to the polishing position. Specifically, the cam member rotating motor **585** is rotated in timed relation to the contact between the processing tool B and the glass sheet A such that the processing tool B having been shifted to the polishing position comes into contact with the edge surface of the glass sheet A. The cam member **581** is driven by the cam member rotating motor **585** and rotated by the second rotation phase. The processing tool B is shifted in conjunction with the cam member **581** rotated by the second rotation phase to reach the polishing position at the time when the processing tool B comes into contact with the glass sheet A. The processing tool B can be shifted in the pressing direction or in the separating direction in the polishing position because the rotary arm member **530** is in the free state.

Step S**606**: The pressing force generation element **510** generates the pressing force that the processing tool B exerts on the edge surface of the glass sheet A. The first processing tool B polishes the edge surface of the glass sheet A from a leading end A**1** to the trailing end A**2** while the pressing force is being generated. Pressed by the trailing end A**2** of the edge surface deviating from the orbit R to the side closer to the processing tool B, the processing tool B is gradually shifted in the separating direction.

When the impact force from the edge surface of the glass sheet A acts on the processing tool B because of the presence of the fine projections on the edge surface of the glass sheet A, the buffering element **520** buffers the impact force while the pressing force generation element **510** generates the pressing force that the processing tool B exerts on the edge surface of the glass sheet A.

Step S**608**: The processing tool B is shifted to the retraction position, whereupon the polishing is finished. Specifically, the cam member **581** is driven by the cam member rotating motor **585** and rotated by the third rotation phase once the polishing by the processing tool B reaches the polishing end position. The processing tool B is shifted in the separating direction to the retraction position in conjunction with the cam member **581** rotated by the third rotation phase. The processing tool B does not move freely in the retraction position because the rotary arm member **530** is in the locked state.

For successively processing another glass sheet A, Steps S**602** to S**608** are repeated.

According to the glass sheet processing apparatus **500** and the glass sheet producing method of the present embodiment, as described with reference to FIGS. **9** to **14**, the processing tool B can be controlled such that it is first retracted in the separating direction away from the edge surface of the glass sheet A once the polishing is finished, and then returned to the standby position. Since the processing tool B is out of contact with the edge surface of the glass sheet A when returned to the standby position, the processing tool B can be prevented from scratching the edge surface of the glass sheet, and the glass sheet A or the processing tool B can be prevented from being damaged because of the scratching.

In addition, according to the glass sheet processing apparatus **500** and the glass sheet producing method of the present embodiment, the rotary arm member **530** is in the locked state, and therefore the processing tool B does not move freely until the processing tool B comes into contact with the edge surface of the glass sheet A. Accordingly, the vibration of the processing tool B to be generated when the processing tool B comes into contact with the edge surface of the glass sheet A to start the polishing can be reduced even if the glass sheet A or the processing tool B is conveyed at a high speed.

In the embodiment described above, α is 1°, but a may not be 1°. Likewise, β is an angle equal to α, but β may be different from α.

In the embodiment described above, the position control section **580** is an essential component, but the buffering element **520** is not necessarily an essential component. Even without the buffering element **520**, the glass sheet processing apparatus **500** can control the processing tool B such that it is shifted in sequence among the three positions: the standby position, the polishing position, and the retraction position. In one embodiment, a glass sheet processing apparatus described hereinafter is within the scope of the present invention.

The glass sheet processing apparatus according to the embodiment of the present invention includes: a pressing force generation element configured to generate a pressing force that a processing tool exerts on an edge surface of a glass sheet; and a position control section configured to control the processing tool such that it is shifted in sequence among a standby position, a polishing position, and a retraction position. Herein, the standby position is where the processing tool is on standby for contact with the edge surface of the glass sheet. The polishing position is where the processing tool is in contact with the edge surface of the glass sheet and is polishing the edge surface. The retraction position is where the processing tool has been retracted in a direction to separate the processing tool from the edge surface of the glass sheet beyond the standby position. In one embodiment, a glass sheet producing method including controlling a processing tool such that it is shifted in sequence among a standby position, a polishing position, and a retraction position is also within the scope of the present invention.

Although a grinding stone is mentioned as an example of the processing tool B, and the processing tool B performs polishing on the edge surface of the glass sheet A in the glass sheet processing apparatuses and the glass sheet producing method of the present invention, the present invention is not limited thereto. The processing tool B may be any tool other than the grinding stone as long as it can process the edge surface of the glass sheet A. Furthermore, the present invention can be applied to any processing on the glass sheet A other than polishing (e.g., grinding) as long as the processing is directed to the edge surface of the glass sheet A.

INDUSTRIAL APPLICABILITY

The glass sheet processing apparatus and the glass sheet producing method of the present invention can be suitably employed for processing of a glass sheet and production of a glass sheet.

REFERENCE SIGNS LIST

A glass sheet
B processing tool
100 glass sheet processing apparatus
110 pressing force generation element

120 buffering element
130 arm member
180 position control section
200 swivel type glass sheet processing apparatus
210 pressing force generation element
220 buffering element
230 rotary arm member
240 support shaft member
250 processing tool rotating motor
260 linkage mechanism
270 glass condition determining section
280 position control section
300 linear slide type glass sheet processing apparatus
310 pressing force generation element
320 buffering element
330 slide member
340 slide rail member
350 processing tool rotating motor
360 linkage mechanism
370 glass condition determining section
380 position control section
410 orifice plate
420 non-return valve
430 piston
440 chamber
H working fluid
450 first linkage member
460 second linkage member
470 fixed shaft
480 piston end portion
490 coil spring
500 glass sheet processing apparatus
510 pressing force generation element
520 buffering element
530 rotary arm member
531 first arm portion
532 second arm portion
540 support shaft member
580 position control section
581 cam member
582 cam follower
583 first cam surface
584 second cam surface
585 cam member rotating motor

The invention claimed is:

1. A glass sheet processing apparatus to process an edge surface of a glass sheet using a processing tool, comprising:

a pressing force generation element configured to generate a pressing force that the processing tool exerts on the edge surface of the glass sheet; and

a buffering element configured to buffer an impact force that the edge surface of the glass sheet exerts on the processing tool, wherein

the buffering element buffers only a first force that the edge surface of the glass sheet exerts on the processing tool without buffering a second force that the processing tool exerts on the edge surface of the glass sheet.

2. The glass sheet processing apparatus of claim **1**, further comprising: a position control section configured to control the processing tool such that it is shifted in sequence among a standby position, a polishing position, and a retraction position, wherein

the standby position is where the processing tool is on standby for contact with the edge surface of the glass sheet,

the polishing position is where the processing tool is in contact with the edge surface of the glass sheet and is polishing the edge surface, and

the retraction position is where the processing tool has been retracted in a direction to separate the processing tool from the edge surface of the glass sheet beyond the standby position.

3. The glass sheet processing apparatus of claim **1**, wherein the buffering element is a dashpot.

4. The glass sheet processing apparatus of claim **3**, wherein the dashpot includes water as a working fluid.

5. The glass sheet processing apparatus of claim **3**, wherein the dashpot includes a piston mechanism, and

the piston mechanism has a non-return valve to be closed to an action of the impact force.

6. The glass sheet processing apparatus of claim **2**, comprising

a rotary arm member and a support shaft member,

wherein the processing tool is connected with the rotary arm member, and the rotary arm member is rotatably connected with the support shaft member, and

the pressing force generation element generates the pressing force by applying a couple of forces to the rotary arm member.

7. The glass sheet processing apparatus of claim **6**, wherein the position control section includes:

a cam member to be rotationally driven; and

a cam follower to be driven by the rotation of the cam member,

the rotary arm member operates in conjunction with the cam follower,

the cam follower is displaced relative to the cam member to apply a couple of forces to the rotary arm member, and

the processing tool is shifted to the standby position, the polishing position, or the retraction position in response to the application of the couple of forces to the rotary arm member.

8. The glass sheet processing apparatus of claim **7**, wherein the cam follower includes a first cam follower and a second cam follower configured to be movable while maintaining a predetermined gap therebetween,

the cam member is a cylindrical end cam having, on one side, a first cam surface capable of being brought into contact with the first cam follower and, on the other side, a second cam surface capable of being brought into contact with the second cam follower,

the processing tool is shifted in sequence among the standby position, the polishing position, and the retraction position by change in the position and state of contact between the first cam surface and the first cam follower, and the position and state of contact between the second cam surface and the second cam follower in conjunction with the rotation of the cam member,

the rotary arm is in a locked state, in which it is non-rotatable, in the standby position and the retraction position, and

the rotary arm is in a free state, in which it is rotatable, in the polishing position.

9. The glass sheet processing apparatus of claim **8**, wherein the processing tool is shifted to the standby position when the cam member is rotated by a first rotation phase,

the processing tool is shifted to the polishing position when the cam member is rotated by a second rotation phase,

the processing tool is shifted to the retraction position when the cam member is rotated by a third rotation phase, a width of the cam member with respect to a portion thereof that comes between the first cam follower and the second cam follower in the case of the first rotation phase and the third rotation phase is equal to the gap between the first cam follower and the second cam follower,

the width of the cam member with respect to a portion thereof that comes between the first cam follower and the second cam follower in the case of the second rotation phase is smaller than the gap between the first cam follower and the second cam follower,

the position of the first cam surface in the case of the third rotation phase is offset toward one side in an axial direction of the cam member by a predetermined distance from the position of the first cam surface in the case of the first rotation phase.

10. The glass sheet processing apparatus of claim **1**, comprising:

a slide member and a slide rail member,

wherein the processing tool is connected with the slide member, and the slide member is connected with the slide rail member in a linearly slidable manner, and

the pressing force generation element generates the pressing force by pressing the slide member.

11. The glass sheet processing apparatus of claim **1**, wherein

the buffering element includes a Scott Russel linkage mechanism configured to convert a direction in which the impact force acts from the horizontal direction into the vertical direction.

12. A glass sheet processing apparatus to process an edge surface of a glass sheet using a processing tool, comprising:

a pressing force generation element configured to generate a pressing force that the processing tool exerts on the edge surface of the glass sheet;

a position control section configured to control the processing tool such that it is shifted in sequence among a standby position, a polishing position, and a retraction position;

a support shaft member; and

a rotary arm member rotatably connected with the support shaft member,

wherein the standby position is where the processing tool is on standby for contact with the edge surface of the glass sheet,

the polishing position is where the processing tool is in contact with the edge surface of the glass sheet and is polishing the edge surface,

the retraction position is where the processing tool has been retracted in a direction to separate the processing tool from the edge surface of the glass sheet beyond the standby position,

the processing tool is connected with the rotary arm member, and

the pressing force generation element generates the pressing force by applying a couple of forces to the rotary arm member.

13. A glass sheet producing method for producing a glass sheet having a processed edge surface by processing the edge surface of the glass sheet using a processing tool, comprising:

generating a pressing force that the processing tool exerts on the edge surface of the glass sheet while buffering an impact force that the edge surface of the glass sheet exerts on the processing tool,

wherein the buffering an impact force includes buffering only a first force that the edge surface of the glass sheet exerts on the processing tool without buffering a second force that the processing tool exerts on the edge surface of the glass sheet.

14. A glass sheet producing method for producing a glass sheet having a processed edge surface by processing the edge surface of the glass sheet using a processing tool, wherein

the processing tool is connected with a rotary arm member,

the rotary arm member is rotatably connected with a support shaft member,

the method comprises controlling the processing tool such that it is shifted in sequence among a standby position, a polishing position, and a retraction position,

the standby position is where the processing tool is on standby for contact with the edge surface of the glass sheet,

the polishing position is where the processing tool is in contact with the edge surface of the glass sheet and is polishing the edge surface,

the retraction position is where the processing tool has been retracted in a direction to separate the processing tool from the edge surface of the glass sheet beyond the standby position, and

a pressing force generation element generates a pressing force that the processing tool exerts on the edge surface of the glass sheet by applying a couple of forces to the rotary arm member when the processing tool is in contact with the edge surface of the glass sheet in the polishing position.

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